CodeWarrior for Microcontrollers V10

Processor Expert User Manual

Help version 4.17

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1. Introduction

Both hardware and software design have progressed so much with the ever-advancing new technologies emerging everyday, but their interrelationships and interdependence have been mostly neglected. On one hand, we often see a good new hardware architecture but the software design is too expensive for such an architecture. On the other hand, the computerization of nearly all mechanical gadgets all over the modern world leads to the use of embedded computer systems. In situations where expense is a consideration, embedded computer systems with efficient software can significantly reduce the overall design cost.

Processor Expert Code Warrior plug-in is designed for **rapid application development** of embedded applications for a wide range of microcontrollers and microprocessor systems.

Processor Expert Main features

- The application is created from **components** called **Embedded Components.**
- Embedded Components encapsulate functionality of basic elements of embedded systems like CPU core, CPU on-chip peripherals, FPGA, standalone peripherals, virtual devices, and pure software algorithms, and change these facilities to properties, methods, and events (like objects in OOP).
- Processor Expert suggests, connects, and generates the drivers for embedded system hardware, peripherals, or used algorithms. This allows the user to concentrate on the creative part of the whole design process.
- Processor Expert allows true **top-down** style of application design - the user starts the design directly by defining the application behavior instead of spending days just trying to make the chip work.
- Processor Expert works with an **extensible components library** of supported microprocessors, peripherals, and virtual devices.
- Processor Expert Peripheral Initialization components generate effective initialization code for all on-chip devices and support all their features.
- Logical Device Drivers (LDD components) are efficient set of Embedded Components that are ready to be used together with RTOS. They provide a unified hardware access across MCUs allowing to develop simpler and more portable RTOS drivers or bare board application. See *3.2.1.2 Logical Device Drivers* for details.
- Processor Expert allows to easily examine the details of the architecture and the relationship between the Embedded Component setup, and CPU control registers initialization.
- The user can create his/her own components using the **Component Wizard** external tool. See *5 Component Wizard Description* for details.

1.1. Processor Expert Plug-in Overview

Processor Expert provides an efficient development environment for rapid application development of the embedded applications. You can develop embedded applications for a wide range of microcontrollers and microprocessor systems using Processor Expert.

Processor Expert is integrated as a plug-in into the CodeWarrior IDE. You can access Processor Expert from the CodeWarrior IDE using the Processor Expert menu in the CodeWarrior IDE menu bar. The Processor Expert plug-in generates code from the Embedded Components and the CodeWarrior IDE manages the project files, and compilation and debug processes.

Figure below shows the Processor Expert plug-in that appears when you select the Processor Expert menu in the CodeWarrior IDE menu bar.

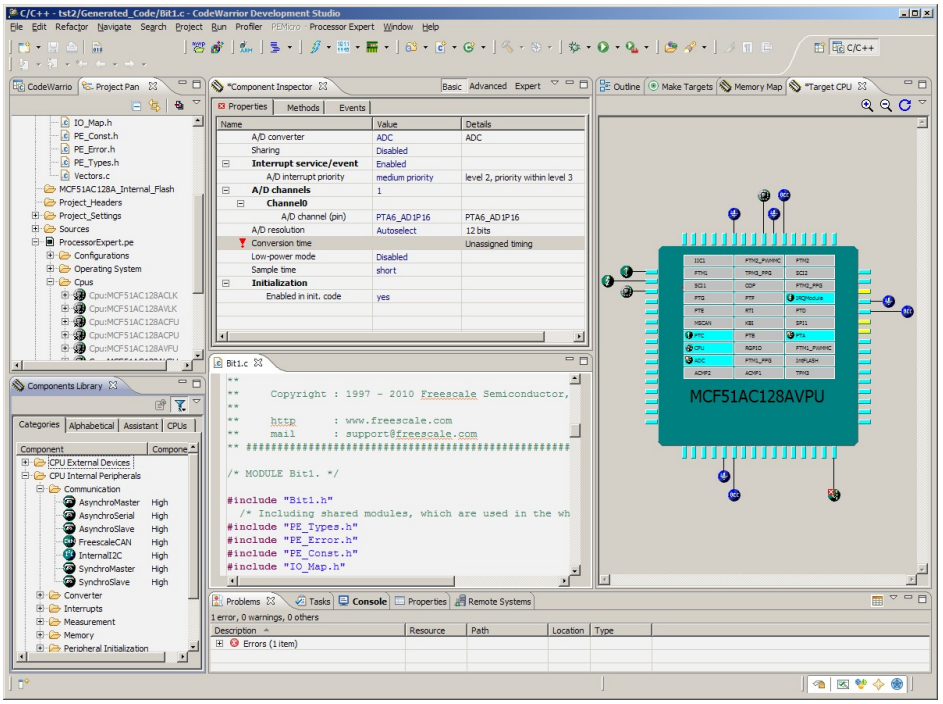


Figure 1.1 - CodeWarrior IDE with Processor Expert plug-in active

How to Create a New Project

See the chapter *4 Processor Expert Tutorials* or *3.1 Quick Start in Processor Expert* for step-by-step instructions on how to create a new Processor Expert project.

Where to find source code and user modules

Processor Expert generates all drivers during the code generation process. The generated files are automatically inserted into the active (default) target in the CodeWarrior project. For more information on generated files please see the chapter *3.5.1 Code Generation*.

1.2. Features

Processor Expert has built-in knowledge (internal definitions) about all microcontroller units and integrated peripherals. The microcontroller units and peripherals are encapsulated into configurable components called Embedded Components, each of which provides a set of useful properties, methods and events.

An intuitive and powerful User Interface (UI) allows the user to define the system behavior in several steps. A simple system can be created just by selecting the necessary components, setting their properties to the required values and maybe also dragging and dropping some of their methods to the user part of the project source code.

Processor Expert Key Components

- Graphical IDE
- Built-in detailed design specifications of the Freescale devices
- Code generator

PE Key Features

- Design-time verifications
- MCU selection from multiple MCU derivatives available
- MCU pin detailed description and structure viewing
- Configuration of functions and settings for the selected MCU and its peripherals
- Definition of system behavior during initialization and at runtime
- Design of application from pre-built functional components
- Design of application using component methods (user callable functions) and events (templates for user written code to process events, e.g. interrupts)
- Customization of components and definition of new components
- Tested drivers
- Library of components for typical functions (including virtual SW components)
- Verified reusable components allowing inheritance
- Verification of resource and timing contentions
- Concept of project panel with ability to switch/port between MCU family derivatives
- Code generation for components included in the project
- Implementation of user written code
- Interface with Freescale CodeWarrior

PE based tool solution offers the following advantages to Freescale MCU customers:

- In all phases of development, customers will experience substantial reductions in
  - development cost
  - development time
- Additional benefits in product development process are
  - Integrated development environment increases productivity
  - Minimized time to learn Freescale MCU
  - Rapid prototyping of entire applications
  - Modular and reusable functions
  - Easy to modify and port implementations

Integrated development environment increases users' productivity

- "This tool lets me produce system prototypes faster because the basic setup of the controller is easier. This could mean that I will implement more of my ideas into a prototype application having a positive effect on the specification, analysis and design phase. PE justifies its existence even when used for this purpose alone!"
- "This system frees you up from the hardware considerations and allows you to concentrate on software issues and resolve them thoroughly."
- "Very good for CPUs with embedded peripherals. It significantly reduces project development time."

Primary Reasons Why Users Feel that Way:

- Processor Expert has built-in knowledge (internal definition) of the entire microcontroller with all its integrated peripherals.
- Processor Expert encapsulates functional capabilities of microcontroller elements into concepts of configurable components.
- Processor Expert provides an intuitive graphical UI, displays the microcontroller structure, and allows the user to take advantage of predefined and already verified components supporting all typically used functions of the microcontroller.
- Applications are designed by defining the desired behavior using the component settings, drag & drop selections, utilizing the generated methods and events subroutines, and combining the generated code with user code.
- Processor Expert verifies the design based on actual microcontroller resource and timing contentions.
- Processor Expert allows the efficient use of the microcontroller and its peripherals and building of portable solutions on a highly productive development platform.

Minimized Time to Learn Microcontroller

There are exciting possibilities in starting a new project if the user is starting from ground zero even if the user is using a new and unfamiliar processor.

- The user is able to utilize the microcontroller immediately without studying the microcontroller's documentation.
- The user is able to implement simple applications even without deep knowledge of programming.
- PE presents all necessary information to the user using built-in descriptions and hints.
- PE has built-in tutorials and example projects.

Rapid Prototyping of Entire Applications

"Processor Expert allows the users to try different approaches in real time and select the best approach for the final solution. Users are not confined to a pre-determined linear approach to a solution."

- Easy Build of application - based on system functional decomposition (top-down approach)
- Easy MCU selection
- Easy CPU initialization
- Easy initialization of each internal peripheral
- Simple development of reusable drivers
- Simple implementation of interrupt handlers
- Inherited Modularity and reuse

- Inherited ease of implementation of system hardware and software/firmware modifications

Modular and Reusable Functions

Processor Expert greatly decreases the start-up time and minimizes the problems of device idiosyncrasies.

- It uses the concept of a function encapsulating entity called Embedded Component with supporting methods and events
- Uses a library of predefined components
- Uses the concept of device drivers and interrupt handlers that are easy to reapply
- Uses the concept of well-documented programming modules to keep the code well organized and easy to understand

Note: Processor Expert Embedded Component were formerly called "Processor Expert Embedded Beans."

Easy to modify and port implementations

Processor Expert allows optimal porting to a previously unused processor.

- Supports multiple devices within a project and makes it extremely easy to switch them
- Supports desired changes in the behavior of the application with an instant rebuild
- Supports interfacing of the CodeWarrior IDE

1.3. Concepts

The main task of **Processor Expert** is to manage CPU and other hardware resources and to allow virtual prototyping and design.

Code generation from components, the ability to maintain user and generated code, and an event based structure significantly reduce the programming effort in comparison with classic tools.

Embedded Components

Component is the essential encapsulation of functionality. For instance, the *TimerInt* component encapsulates all CPU resources that provide timing and hardware interrupts on the CPU.

Name	Value	Details
Component name	TI1	
Periodic interrupt source	FTM2free	FTM2free
Counter	FTM2	FTM2
⊟ Interrupt service/event	Enabled	
Interrupt	Vftm2fault_ovf	Vftm2fault_ovf
Interrupt priority	medium priority	level 4, priority within
Interrupt period	500.0 ms	500 ms
Component uses entire timer	no	
⊟ Initialization		
Enabled in init. code	yes	
Events enabled in init.	yes	

Figure 1.2 - Example of TimerInt component (periodical event timer) properties

You'll find many components that we call Embedded Components in the Processor Expert Components library window. These components are designed to cover the most commonly required functionality used for the

microcontroller applications - from handling port bit operations, external interrupts, and timer modes up to serial asynchronous/synchronous communications, A/D converter, I2C, CAN etc.

A component provides a **clear interface**. By setting **properties**, a user defines the future behavior of the component in runtime. The user controls properties in design time by using the Component Inspector. Runtime control of the component function is done by the **Methods**. **Events** are interfacing hardware or software events invoked by the component to the user's code.
The user can enable or disable the appearance (and availability) of methods of the component in generated source code. Disabling unused methods could make the generated code shorter. See *3.6.1 General Optimizations* for details.

Events, if used, can be raised by interrupt from the hardware resource such as timer, SIO or by pure software reason, such as overflow in application runtime. You can enable or disable interrupts using component **methods** and define priority for event occurrence and for executing its Interrupt Service Routine (ISR). The hardware ISR provided by the component handles the reason for the interrupt. If the interrupt vector is shared by two (or more) resources, then this ISR provides the resource identification and the user is notified by calling the **user event handling code.**

Creating Applications

Creation of an application with Processor Expert on any microcontroller is very fast. To create an application, first choose and set up a CPU component, add other components, modify their properties, define events and select Generate Code. Processor Expert generates all code (well commented) from components according to your settings. See *3.5.1 Code Generation* for details.

This of course is only part of the application code that was created by the "virtual application engineer" - Processor Expert CPU knowledge system and solution bank. The solution bank is created from hand written and tested code optimized for efficiency. These solutions are selected and configured in the code generation process.

Enter your code for desired events, provide main code, add existing source code - and build the application using classic tools - compiler, assembler - and debug it before the final burn-in. These are typical steps when working with Processor Expert.

Other components may help you to very quickly include pictures, files, sounds, and string lists in your application .

Processor Expert has built-in knowledge (internal definitions) about the entire MCU with all integrated peripherals. The MCU units and peripherals are encapsulated into configurable components called Embedded Components and the configuration is fast and easy using a graphical Component Inspector.

Peripheral Initialization Components are a subset of Embedded Components allow the user to **setup initialization of the particular on-chip device** to any possible mode of operation. The user can easily view all initialization values of the MCU produced by Processor Expert with highlighted differences between the last and current properties settings.

Processor Experts performs a **design time checking of the settings** of all components and reports errors and warnings notifying users about wrong property values or conflicts in the settings with other components in the project.

Processor Expert contains many **useful tools for exploring a structure of the target MCU** showing the details about the allocated on-chip peripherals and pins.

Processor Expert generates a **ready-to-use source code** initializing all on-chip peripherals used by the component according to the component setup.

RTOS support

Processor Expert provides a set of LDD components (Logical Device Drivers) that support generation of driver code that can be integrated with RTOSes (Real Time Operating Systems). Please see details in the section *3.2.1.2 Logical Device Drivers*

1.4. Benefits of Embedded Components and Processor Expert Technology

The key benefit of **Embedded Components** is same as using components in software design environments such as Microsoft Visual Basic or Borland Delphi. In comparison with components used within these products, Embedded Components provide hardware encapsulation in the form of a platform-independent standard. Different players in the embedded market should benefit from such a standardized approach.

Microprocessor producers

Each year microprocessor producers introduce many new microprocessor families or derivatives. As the complexity of microprocessors increases, programmers must handle more and more registers to get the required functionality. Classical development tools usually do not support the rapid prototyping phase of design, and classical programming languages are unable to describe the on-chip peripherals structure efficiently. On the other hand, microprocessor producers need to speed up the learning, design and coding processes for their customers.

For the designers, Processor Expert and its configuration and code generation features eliminate the necessity to be otherwise preoccupied with the hardware dependencies. Processor Expert could also even suggest the right member of a microprocessor family for the specific application.

Producers of intelligent peripheral I/Os and other devices

Complex and feature-rich peripherals and controllers require immense efforts to use them efficiently, even if device drivers are supplied by the factory. But imagine the possibility of supporting customers with components providing a standard software interface that allows building applications and using new hardware device features easily.

The Processor Expert environment allows this — customers can easily download new components from the internet and install them into Processor Expert.

Producers of hardware of microprocessor systems

Microprocessor boards that are to be programmed by a customer must be well supported by software. Processor Expert can handle software configuration and generation of drivers for microprocessor devices and off-chip peripheral devices. Creating an application using Processor Expert takes usually 70% less time than with standard Integrated Development Environments (IDEs) containing only a source code editor/compiler/debugger.

Producers of OS

Processor Expert can be used to build an OS kernel or OS drivers. Also, due to its open component architecture and support of pure software components, Processor Expert can be used to build applications benefiting from underlying operating system services.

Educational institutes

Microprocessor-oriented courses can benefit from the information available in Processor Expert about microprocessor structures and hardware independence delivered by Processor Expert. Design of applications begins with definition of functionality, which can be obtained very quickly by building the application from Embedded Components. Students can get the results very fast without facing problems that are not related to the subject of the course, for example compiler bugs and errors in the documentation.

Hardware and software developers

Shortening of the design and learning phase, speeding up of the deployment of new components, full use of hardware using tested software components, reduction in time and cost of design — all these are keys to success provided by Processor Expert.

1.5. Terms and Definitions Used in Processor Expert

Component - An Embedded Component is a component that can be used in Processor Expert. Embedded Components encapsulate the functionality of basic elements of embedded systems like CPU core, CPU on-chip peripherals, standalone peripherals, virtual devices and pure software algorithms and wrap these facilities to properties, methods, and events (like objects in OOP). Components can support several languages (ASM, ANSI C, Modula and others) and the code is generated for the selected language.

Component Inspector - Window with all parameters of a selected component: properties, methods, events.

Bus clock - A main internal clock of the CPU. Most of the CPU timing is derived from this value.

CPU Component - Component that encapsulates the CPU core initialization and control. This component also holds a group of settings related to the compilation and linking, such as Stack size, Memory mapping, linker settings. Only one CPU component can be set active as the target CPU. See *3.2.2 CPU Components* for details.

Component Driver - Component drivers are the core of Processor Expert code generation process. Processor Expert uses drivers to generate the source code modules for driving an internal or external peripheral according to the component settings. A Component can use one or more drivers.

Counter - Represents the whole timer with its internal counter.

Events - Used for processing events related to the component's function (errors, interrupts, buffer overflow etc.) by user-written code. See *3.2.1 Embedded Components* for details.

External user module - External source code attached to the PE project. The external user module may consist of two files: implementation and interface (*.C and *.H).

Free running device - Virtual device that represents a source of the overflow interrupt of the timer in the free running mode.

High level component - Component with the highest level of abstraction and usage comfort. An application built from these components can be easily ported to another microcontroller supported by the Processor Expert.

They provide methods and events for runtime control. See *3.2.1.1 Component Categories* for details.

Internal peripherals - internal devices of the MCU such as ports, timers, A/D converters, etc. usually controlled by the CPU core using special registers.

ISR - Interrupt Service Routine — code which is called when an interrupt occurs.

LDD components - Logical Device Driver components. The LDD components are efficient set of components that are ready to be used together with RTOS. They provide a unified hardware access across MCUs allowing to develop simpler and more portable RTOS drivers. See *3.2.1.1 Component Categories* for details.

Low level component - a component dependent on the peripheral structure to allow the user to benefit from the non-standard features of a peripheral. The level of portability is decreased because of this peripheral dependency. See *3.2.1.1 Component Categories* for details.

MCU - Microcontroller Unit — microcontroller used in our application.

Methods - user callable functions or sub-routines. The user can select which of them will be generated and which not. Selected methods will be generated during the code generation process into the component modules.

Module - Source code module — could be generated by Processor Expert (Component modules, CPU Module, events.c) or created by the user and included in the project (user module).

OOP - Object-oriented programming (OOP) was invented to solve certain problems of modularity and reusability that occur when traditional programming languages such as C are used to write applications.

PE - Abbreviation of Processor Expert that is often used within this documentation.

Peripheral Initialization component - encapsulates the whole initialization of the appropriate peripheral. Components that have the lowest levels of abstraction and usage comfort. See *3.2.1.1 Component Categories* for details. They usually do not support any methods or events except the initialization method. The rest of the device driver code needs to be written by hand using either PESL or direct control of the peripheral registers. See *3.8 Low-level Access to Peripherals* for details.

Popup menu - this menu is displayed when the right mouse button is pressed on some graphical object.

PLL - Phase Locked Loop. This circuit is often built-in inside the CPU and can be used a main source of the clock within the CPU.

Prescaler - A fixed or configurable device that allows to divide or multiply a clock signal for a peripheral CPU peripheral or its part.

Properties - Parameters of the component. Property settings define which internal peripherals will be used by the component and also initialization and behavior of the component at runtime.

RTOS - Real Time Operating System is an operating system (OS) intended for real-time applications.

Target CPU - The CPU derivative used in a given project.

Template - Component Template — component with preset parameters.

User-defined Component Template - User-defined component template is a component with preset parameters saved under a selected name. Also the name of the author and short description can be added to the template.

User module - Source code module created or modified by the user. (Main module, event module or external user module).

Xtal - A crystal - a passive component used as a part of an oscillator circuit.

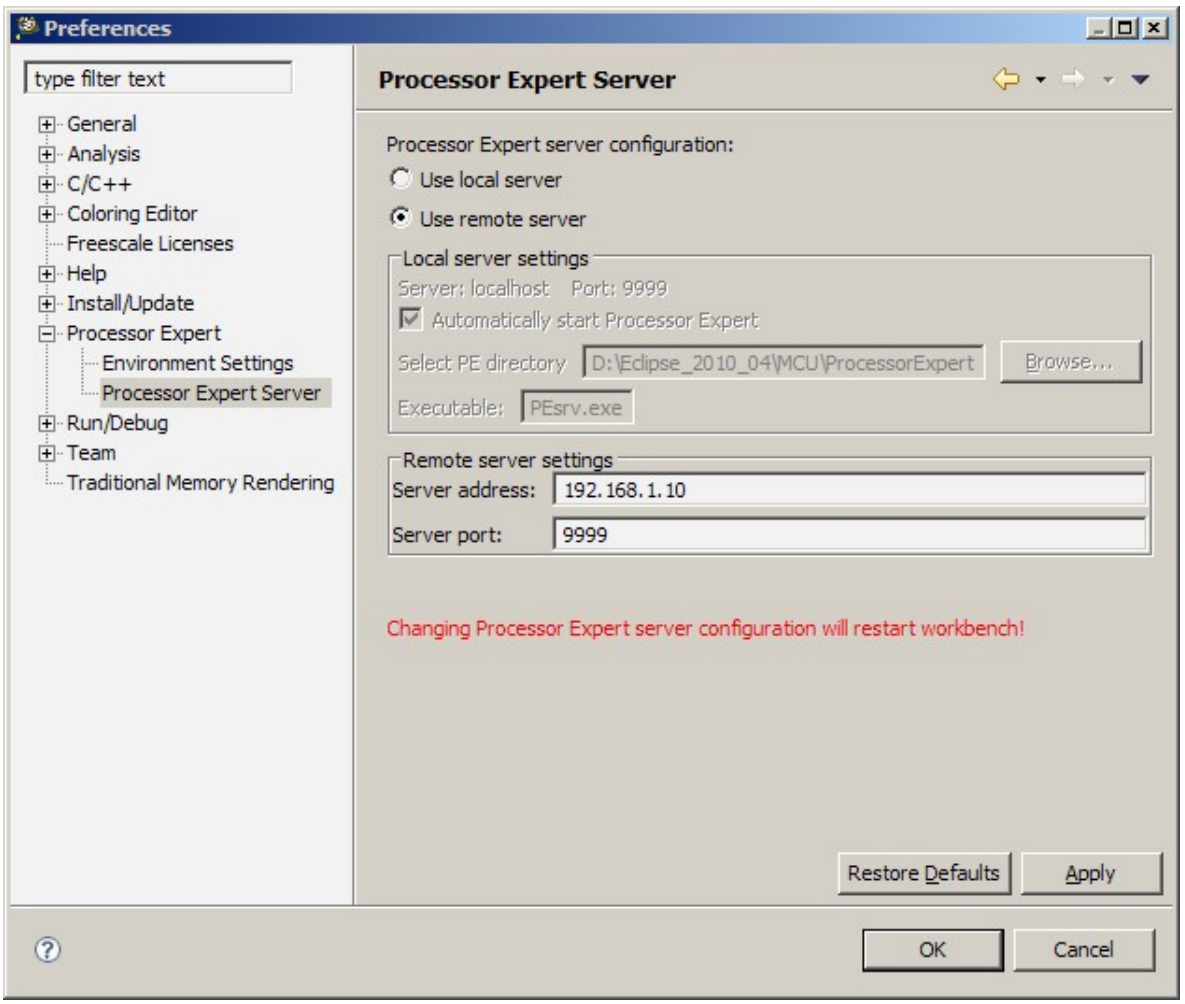
1.6. Using Processor Expert on Linux

Even though the CodeWarrior can be run on Linux, the current version of Processor Expert core still needs to be run in Windows environment. It's necessary to have a working windows CodeWarrior installation. Processor Expert core runs there as a background service and communicates with native Eclipse user interface.

Using Windows Machine to Host Processor Expert

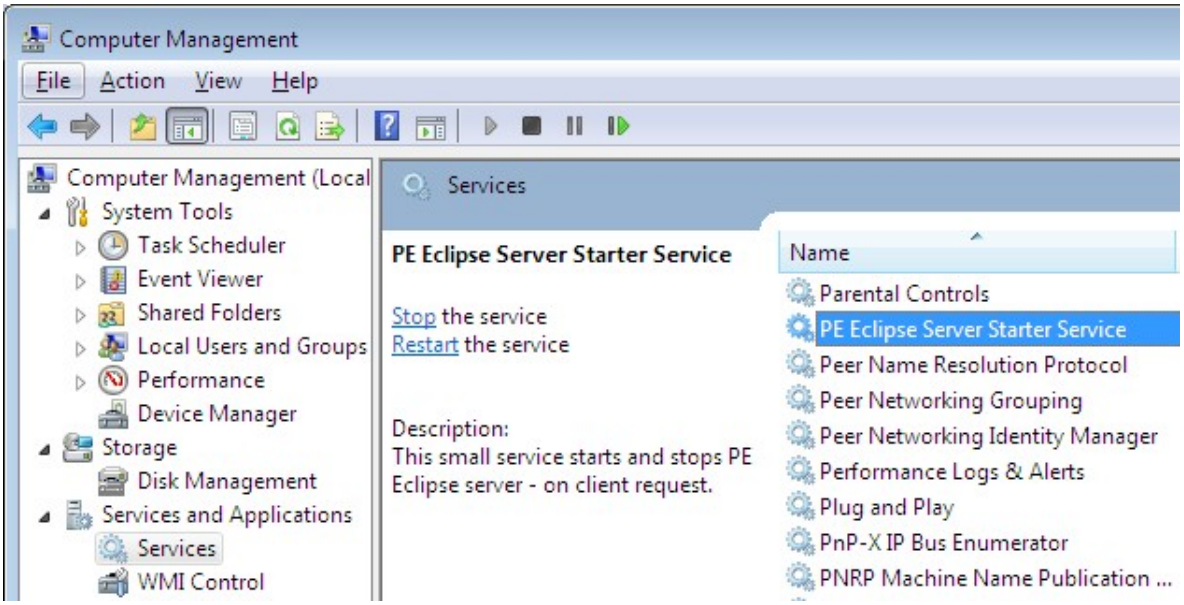
It's necessary to have a windows machine with installed the Windows version of the same version of CodeWarrior installer.

When the CodeWarrior on Linux is run for the first time, it's necessary to configure Windows machine IP address in CodeWarrior Preferences.

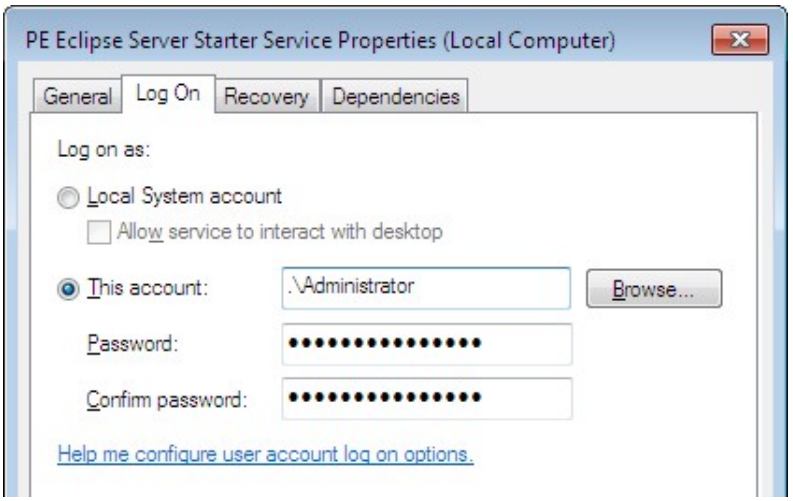


On the windows machine, in case that Windows 7 or Windows Vista operating systems are used, it's necessary to configure PE service to run with administrator rights. Please use the following steps:

- Open the Computer Management window and select **Services and Applications** > **Services**
- Find **PE Eclipse Server Starter Service** and open it's peroperties using the pop-up menu



- In the **Log On** tab select **This account** and select an administrator account.



Using Wine

Please note that this solution is provided as-is without any warranty or support!

It has been reported that Processor Expert service can also run with Wine without using second machine with real windows. Here are the steps that needs to be done:

1. Install "wine" and "winetricks" packages for your distribution. For example (in distributions using apt-get):
```
#!/bin/sh
sudo apt-get install wine
# tested with wine version wine-1.0.1
wget http://www.kegel.com/wine/winetricks
# sudo apt-get install cabextract
./winetricks msxml3 msxml6 winxp
```
2. Start the CodeWarrior IDE, Select Window / Preferences and choose Processor Expert / Processor Expert

Server. Then select User remove server and set the remote server settings to address **127.0.0.1** and port **9999**.

3. The close CodeWarrior and start PEsrv.exe calling the following command in the {CW_instal_dir}/MCU/ProcessorExpert directory:

```
wine PEsrv.exe
```

4. Start CodeWarrior and Processor Expert should be working.

2. User Interface

Processor Expert menu is integrated as a plugin in the CodeWarrior IDE offering set of views. There is also a menu item named **"Processor Expert"** offering PE-related commands.
See Processor Expert plug-in Main menu page for description of individual items.

The user interface of Processor Expert consists of the following windows :

Project Editing Windows

- Project panel - Shows projects with files and components within the projects.
- Inspector - Allows the user to setup components of the project.
- Components Library - Shows all supported components including CPU components and component templates.
- Target CPU - Shows CPU package, structure and components connected to internal peripherals.

Project Information Windows

- Peripheral Initialization - Shows overview of the peripheral initialization settings for the current CPU.
- Memory Map - Shows the CPU address space and internal and external memory mapping.

2.1. Main Menu

The Processor Expert Plug-in is integrated into the CodeWarrior Eclipse IDE as plugin application. The IDE main menu contains a new menu item named "Processor Expert".

The Processor Expert menu includes the following command(s):

- **Component Wizard** - Invokes Component wizard tool. See *5 Component Wizard Description* for details.
- **Show views** - Shows standard Processor Expert windows in case they are hidden.
- **Hide views** - Hides Processor Expert views.
- **Import package** - This command allows to select and install Processor Expert update packages (.PEUpd) files. These files can be for example created in Component Wizard by exporting a user's component.

For commands related to individual projects please follow to *2.2 Project Panel View*.

For Processor Expert related settings and options please follow to *2.1.1 Processor Expert Options*.

2.1.1. Processor Expert Options

Project Options

Project options related to Processor Expert can be found in **Properties** dialog available using the command **Project > Properties**. Then select Processor Expert page in the list on the left. Description of the individual options can be found in the hint window displayed when the cursor is placed on an item.

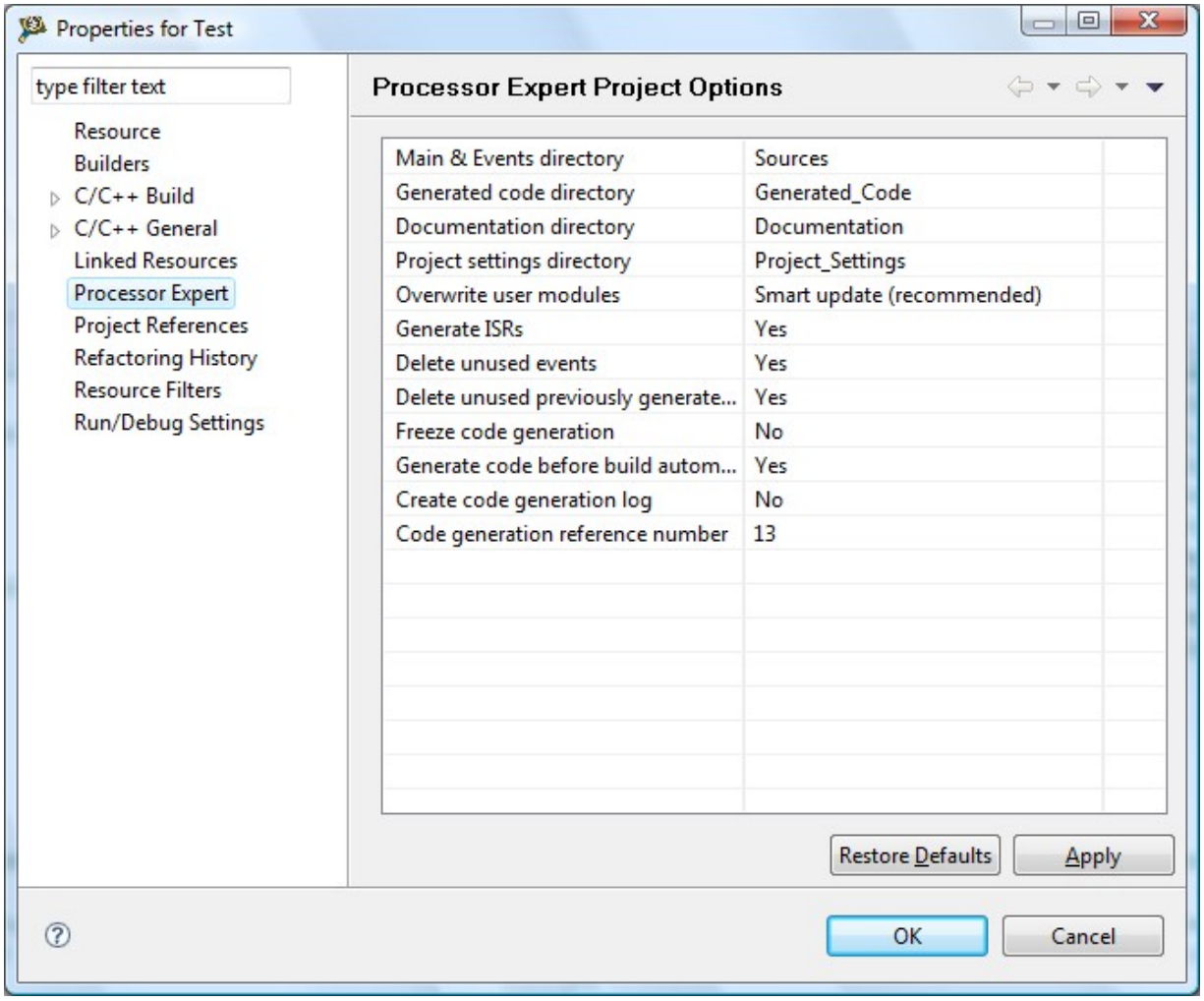


Figure 2.1 - Project Properties Dialog

Preferences

Global settings related to Processor Expert can be found in **Preferences** dialog available using the command **Window > Preferences**. The PE related items can be found under Processor Expert in the list on the left. Description of the individual options can be found in the hint window displayed when the cursor is placed on an item.

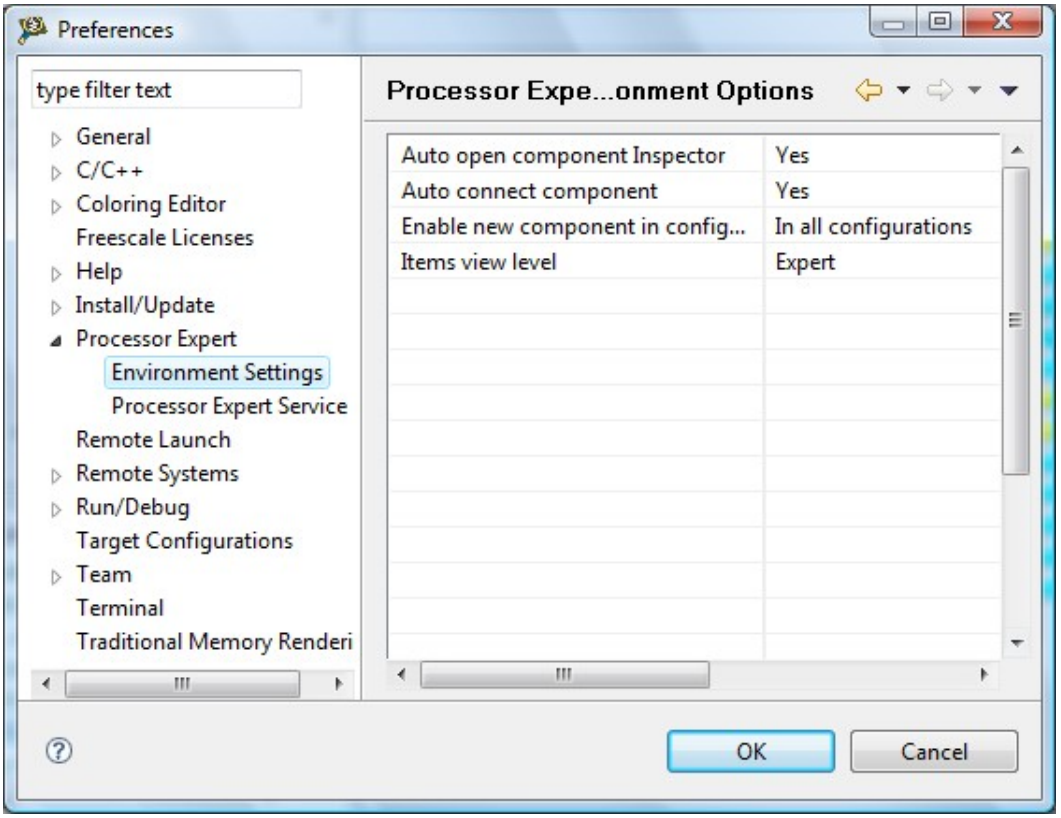


Figure 2.2 - Preferences Dialog

2.2. Project Panel View

Processor Expert project panel shows the project tree with the Processor Expert items listed within the **ProcessorExpert.pe** project branch.

When the user unfolds the Processor Expert project files the following items are shown:

- **Configurations** of the project.
- **Operating System** - contains special components that provide operating system interface and configuration if there are any used.
- CPUs (**CPU components**) included in the project
- **Embedded Components** included in the project. Every component inserted in the project is displayed in the project panel and has a sub tree showing
  - **Methods** - Methods allow runtime control of the component's functionality.
  - **Event routines** - Events allow handling of the hardware or software events related to the component. If the event is disabled, the name of the event is shown. For enabled events, the name of the handling function is shown.
  - **ISRs** - Represent component-related interrupt routines that can be created by the user for low-level interrupt processing. For items, whose ISR names have been specified within component settings, a user-specified name of an ISR and name of the interrupt vector is shown. If an ISR name is not specified (interrupt has to be disabled in this case), only the interrupt vector name is present.

All component's items have status icons that signify the enabled ( ) or disabled ( ) state. If this state cannot be changed directly, the background of the icon is gray. For more details please see chapter *3.2.1 Embedded Components*.

Project Pop-up Menu

This menu is available using right-click at the **ProcessorExpert.pe** file. It contains the standart CodeWarrior commands (please refer to the documentation for the description) with the following PE specific commands:

- **Generate Processor Expert Code** - Invokes code generation for the current project. The generated files are automatically inserted into the active (default) target in the CodeWarrior's project. Generated files corresponding to the Embedded Components can be accessed from the "Code" folder. See *3.5.1 Code Generation* for details.

Component Pop-up Menu

- **Inspector** - Opens Component Inspector window for the component.
- **Code Generation** - Allows to disable/enable of generated module for the component.
- **View source** - Opens the generated code from the selected component for the source code editor. Please note that the code is available only after successful code generation.
- **Component Enabled** - Enables/disables component in the project.
- **Remove component from project** - Deletes the component from the project.
- **Help on component** - Shows on-line help for the component.
- **Save Component Settings As Template** - Creates a template of the selected component. See *3.3.5 Creating User Component Templates* for details.
- **Peripheral Initialization** - Opens the Peripheral Initialization view for the peripheral initialized by the selected bean. See *2.7 Peripheral Initialization View* for details.

Method/Event Pop-up Menu

- **View Code** - Opens code editor at the code of the selected method/event.
- **Toggle Enable/Disable** - Enables/Disables the Method/Event.

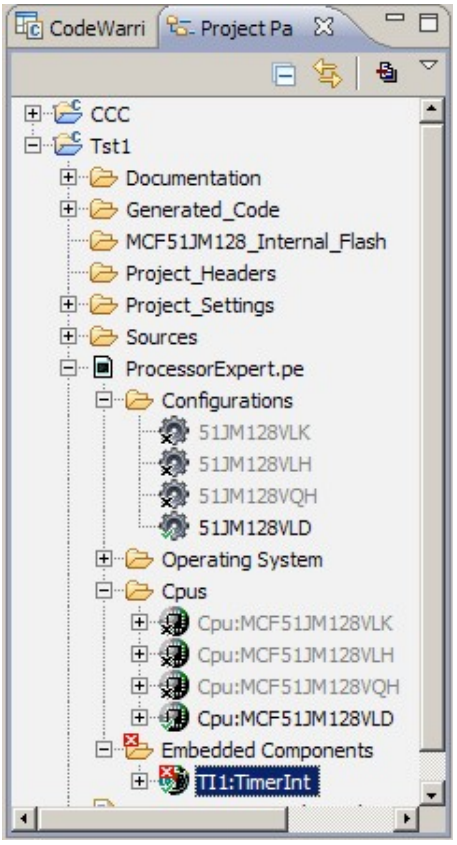


Figure 2.3 - Processor Expert in the Project Panel

2.3. Components Library View

Components Library shows supported embedded components including CPU components and component templates. It lets the user select a desired component or template and add it to the project.

Modes

The Components Library has the following four tabs allowing the user to select components in different modes:

- **Component Categories** - Contains all available components. The components are sorted in a tree based on the categories defined in the components. See *3.2.1.1 Component Categories* for details. Please see below for menu and control details.
- **Alphabetical** - Shows alphabetical list of the available components.
- **Assistant** - Guides the user during the component selection process. The user answers a series of questions that finally lead to a selection of a component that suits best for a required function. See *2.3.1 Component Assistant* for details.
- **CPUs** - Contains list of the available CPU components.

Component names are colored black and the component template names are colored blue. The components that are not supported for the currently selected target CPU are gray. By **double-clicking on the component**, it is possible to insert the component into the current project. The description of the component is shown in a hint.

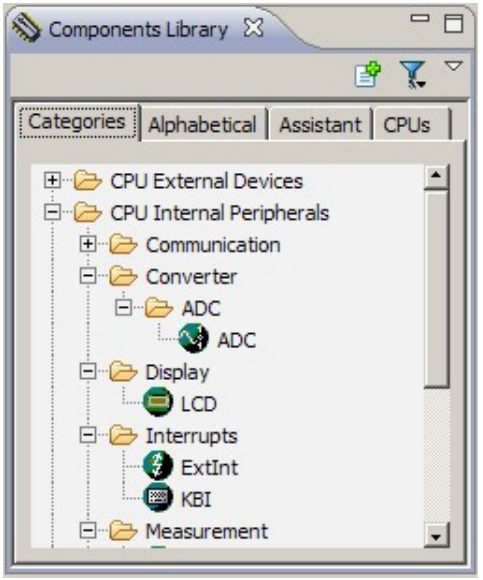
Filtering

Filter can be activated using the filtering icon . If it's active, only the components that could be used with the currently selected target CPU derivative are shown .
If the filter is inactive, Processor Expert also shows components that are not available for the current CPU.

Pop-up menu

A **pop-up menu** opens by right-clicking a component or folder. It contains the following commands:

- **Add to project**- Adds the component to the current project.
- **Expand all** - Expands the folder and all its subfolders.
- **Collapse all** - Collapses the folder and all its subfolders.
- **Refresh**- Refreshes the view area.
- **Deleted Selected Template** - This option is available only for templates. Removes the template from the Components Library.
- **Help on component** - Opens help information for the selected component.



2.3.1. Component Assistant

The Component Assistant is a mode of Components Library window. It guides the user during the selection of components, that is basic application building blocks. The user answers a series of questions that finally lead to a selection of a component that suits best for a required function. In this mode the Components Library window consists of the following parts:

- Control bar with the history navigation buttons and the history line showing answers for already answered questions. The user can walk through the history using the arrow buttons and by clicking the individual items
- A box with a current question.
- A list of available answers for the current question.
  If the answer already corresponds to a single component (it has an icon of the component and there is a [component name] at the end of the list line) and user double-clicks it, its added into the project. Also, you can right-click on the line to open the **pop-up menu** of the component, allowing to add it into the project or

view its documentation (for details see *2.3 Components Library View* help page).
If more questions are necessary for the component selection, the line with the answer contains a group icon and in brackets a number of components that still can possibly be selected. After clicking on such line a next question is displayed.

This mode of Components Library doesn't offer addition of CPU components. If you would like to add another CPU component, please switch to another Components Library tab.

2.4. Inspector View

Inspector allows to view and edit attributes of the item selected in the Project Panel.

Window Columns

Inspector window contains the three columns:

- **Name** - Name of the item to be selected. Groups of items may be collapsed/expanded by double clicking on the first line of the group with its name, it has '+' or '-' sign on the left.
- **Value** - the settings of the items are made in this column. See chapter *2.4.1 Inspector Items* for list of item types.
- **Details** - the current setting or an error status may be reflected on the same line, in the rightmost column of the inspector.

Read only items

Any item can be marked as read-only so the user could not change its content. Read only values are gray.

View mode buttons

They are placed at the top of the window (Basic, Advanced, Expert). These buttons allow users to switch complexity of the view of the component's items. See *2.4.2 Items Visibility* for details.

Pop-up Menu

This menu is invoked by right-clicking a specific inspector item. The menu contains the following commands:

- **Expand All** - if a group is selected, expands all items within the selected group. Otherwise, all groups in the Inspector are expanded. If the expanded group contains any groups that are disabled (gray), the user is asked if the disabled groups should all be expanded.
- **Collapse All** - if a group is selected, collapses all items within the selected group. Otherwise, all groups in the Inspector are collapsed.
- **Help on Component** - shows a help page for the component.

2.4.1. Inspector Items

The following types of the items could be found in the Inspector

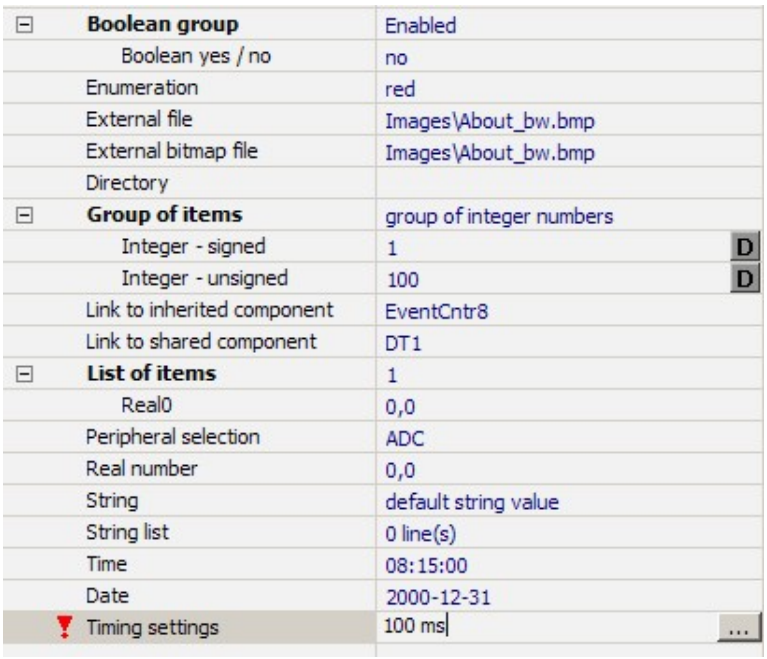


Figure 2.5 - Types of inspector items

Descriptions

- **Boolean Group** - A group of settings controlled by this boolean property. If the group is enabled, all the items under the group are valid; if it is disabled, the list of items is not valid. Clicking the + sign will show/hide the items in the group but doesn't affect value or validity of the items.
- **Boolean yes / no** - The user can switch between two states of the property using a drop-down menu.
  The **Generate code / Don't generate code** settings of methods and events works the same way and determines whether the implementation code for the corresponding method or event will be generated or not (you may thus generate only the methods and events used by your application).
- **Enumeration** - Selection from a list of values. If the user clicks the arrow icon ( ), a list of the possible values for the property is offered.
- **Enumeration Group** - A list of items. Number of visible (and valid) items in the group depends on chosen value. Clicking the arrow icon ( ) will show a list of the possible values of the property. Clicking the + sign shows/hides the items in the group but doesn't influence value or validity of the items.
- **File/Directory Selection** - Allows to specify a file or directory. Clicking the ... icon opens a system dialog window allowing to select a file/directory.
- **Group** - A list of items that can be expanded/collapsed by clicking on the plus/minus icon or by double-clicking at the row. Values of the items in the group are untouched.
- **Integer Number** - The user can insert a number of a selected radix. Radix of the number could be switched using the icons D H B (D = Decimal ,H = Hexadecimal, B = Binary). Only reasonable radixes are offered for the property. If the radix switching icon is not present, Processor Expert expects the decimal radix.
- **Link to Inherited component** - The down-arrow button allows to change the ancestor from the list of possible ancestor. See *3.3.7 Component Inheritance and Component Sharing* for details.

- **Link to shared component** - The down-arrow button allows to change the component from the list of the available components or add a new component to the project. See *3.3.7 Component Inheritance and Component Sharing* for details.
- **List of items** - A list of items may be expanded/collapsed by clicking on the plus/minus button in the left side of the row or by double clicking on the row. The user may add/remove items by clicking on the plus/minus button. The items in the list can be arranged using the related pop-up menu commands.
- **Peripheral selection** - The user can select a peripheral from the list of the available peripherals. The peripheral that are already allocated have the component icon in the list. The properties that conflicts with the component settings have the red exclamation mark.
- **Real Number** - The user can insert any real (floating point) number.
- **String** - Allows to enter any text or value
- **String list** - Clicking the dialog button opens the simple text editor that allows to enter an array of text lines.
- **Time, Date** - Allows to setup the Time/Date in a format according to the operating system settings.
- **Timing settings** - Allows a comfortable setting of the component's timing. The timing dialog box opens on clicking on . See *2.4.3.1 Dialog Box for Timing Settings* for details.

2.4.2. Items Visibility

Processor Expert supports **selectable visibility** of the component items. Each item is assigned a predefined level of visibility. **Higher visibility level** means that items with this level are more special and rarely used than the others with the lower visibility level. Component Inspector displays only items on and below the selected level. It could help especially beginners to set only basic properties at first and do optimization and improvements using advanced and expert properties or events later. There are three visibility levels:

- **Basic view** - The key and most often used items that configure the basic functionality of the components. To view these items, select command **Items Visibility > Basic view** in the Inspector window.
- **Advanced view** - All items from Basic view and the settings that configure some of more advanced and complex features of the component. To view these items, select command **Items Visibility > Advanced view** in the Inspector window.
- **Expert view** - Maximum visibility level - All possible settings, including all settings from basic and advanced view. To view these items, select command **Items Visibility > Expert view** in the Inspector window.

See also the main page of the Component Inspector chapter for more information how to switch view modes.

Note: If an error occurs in a property with a higher visibility level than the level currently selected, then too this error is displayed.

2.4.3. Component Inspector

Component inspector is one of the Inspector window variants. It allows to setup **Properties**, **Methods**, and **Events** of a component.

Note: Property settings influencing the hardware can often be better presented by the CPU package view using the Target CPU window. See 2.5 Target CPU View for details.

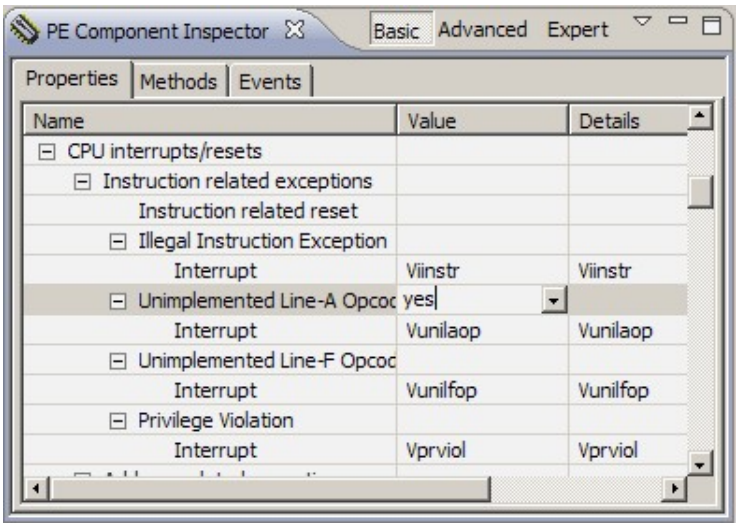


Figure 2.6 - Component Inspector Window

The **Build options** page is present **only in the CPU component** and it provides access to the settings related to linker and compiler.

The **Used** page shows list of the CPU component resources. The user can also manually block individual resources for using them in Processor Expert.
The page consists of the three columns:

- First shows the name of the resource. Resources are in groups according to which device they belong to.
- Second column allows the user to reserve resource (for example pin) for external module. Click on icon to reserve/free a resource. **Reserved resource could not be use in Processor expert any more.**
- Third column shows the current status of the resource and the name of the component which uses it (if the resource is already used).

For more details on component inspector items, please see also the following sub-chapters

- Dialog Box for Timing Settings
- Syntax for the Timing Setup in the Component Inspector

2.4.3.1. Dialog Box for Timing Settings

The **Timing** dialog box provides a user-friendly interface for the settings of the component timing features. When you click the ... button of a timing item in the Component Inspector, the Timing dialog box is displayed.

Before you start to edit component timing you should set:

- **Target CPU** in the Project Panel
- **Used peripherals** in the component's properties
- **Supported speed modes** in the component's properties

The settings are instantly validated according to the Processor Expert timing model. For details on the timing settings principles please see the chapter *3.3.4 Timing Settings*.

Timing Dialog Box Controls

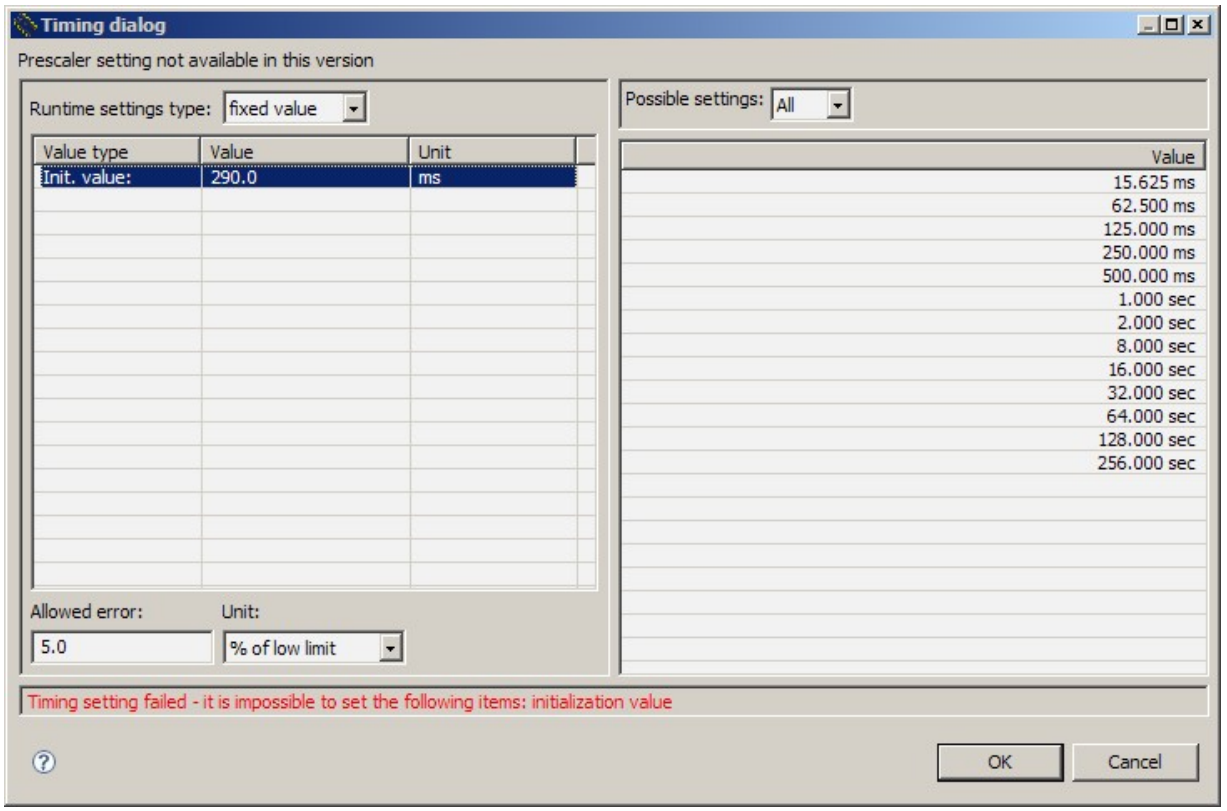


Figure 2.7 - Timing Settings Dialog

Runtime setting configuration

Note: Runtime setting cannot be selected in the BASIC view mode.

Runtime setting type selection determines how the timing setting can be modified at runtime. The following options are available:

- **fixed value** - Timing cannot be changed at runtime.
- **from a list of values** - Allows to change the timing by selecting one of predefined values (from the list) using component method "SetXXXMode". This method sets the value(s) corresponding to the selected timing into the appropriate prescaler and other peripheral register(s). The values (modes) in the list can be

added/removed by editing the timing values table.

- **from interval** - Allows to change a timing freely within a selected interval, while all values of the interval are selected with specified precision. Prescaler value is fixed in this mode, timing is set only using compare/reload registers value. **It means that it has to be possible to reach all values within the interval by using the same prescaler.**
  Please note that this kind of runtime setting requires runtime computations that can be time and space consuming and may not be supported on all microcontrollers.

Note: Some of the methods used for runtime setting of timing will be enabled only if the appropriate runtime setting type is selected.

Timing values table

This table allows to set or modify a requested value(s) for the configured timing. Each row represents one time value and the number of rows depends on the selected type of runtime setting.

- For the option "*fixed value*", there is only one row (Init.Value) containing the fixed initialization value.
- For the option "*from a list of values*", there is one row for each of the possible timing modes. It is possible to enter 16 possible values (modes). The empty fields are ignored. The user can drag and drop rows within the table to change their order. *Please see the section Runtime setting configuration* within this chapter for more information.
- For the option "*from interval*", the table has three rows that contain the Initial value, low limit and high limit of the interval. Please see the section *Runtime setting configuration* within this chapter for details on this type of runtime setting.

There are two editable columns:

- **Value** - Fill in a requested time value (without units). The drop-down arrow button allows to display a list of neighboring values and the user can select one of them. There is also possible to set the value by double-clicking on a value from the possible settings table (see below).
- **Units** - Inits for the value. When the **Recalculate on unit change** check-box below the table is checked, the value (in the previous column) is automatically re-calculated to be the same in the newly selected units.

Timing precision configuration

It is possible to specify desired precision of the timer settings by using one of the following settings (which one is used depends on the type of the timing) :

- The field **Error allowed** allows to specify a tolerated difference between the real timing and the requested value. The **Unit** field allows to specify the units for the error allowed field (time units or a percentage of the requested value).
- The **Min. resolution** field is used for setting interval or capture component timing. Allows the user to specify maximal acceptable length of one tick of the timer.
  In the case of interval settings type, the **% of low limit** (percentage of the low limit value) can be used as the unit for this value.

Minimal timer ticks

Note: This item is available only for setting of period in components where it's meaningful, for example PWM, PPG.

This item allows to set a minimal number of timer-ticks in period. It means that it will be possible to set a duty of the output signal to at least the specified number of distinct values for any period of the output signal at runtime.

Value 0 means no requirements for the timer settings.

Adjusted values

This table displays a real values for each speed mode the currently selected row in the Timing values table. These values are computed from the chosen on-chip peripheral settings, selected prescaler(s) value and the difference between a value selected by the user and the real value.

Status box

The status box displays a status of the timing setting(s). If the timing requirements are impossible to meet, a red error message is displayed, otherwise it's blank and gray.

Possible settings table

This table is displayed on the right side of the timing dialog box when you click the **Possible settings** button on the top. The table shows values supported by the target CPU for the selected peripheral.

If there are only individual values available to set, the table contains a list of values - each row represents one value. If there are intervals with a constant step available, each row contains one of the intervals with three values: **From**, **Till** - minimum and maximum value, **Step** - a step between values within the interval.

The way the values are displayed may be dependent on

- Runtime setting type - If it's "fixed value" or "from list of values" — the values present in more rows (overlapping intervals) are shown only once. If the "from time interval" runtime setting type is used, all intervals that can be set by various prescalers combinations are shown, even if they overlap. It's because intervals can differ in resolution, that is number of individual timing steps that can be achieved within them.
- Timing unit - If a frequency unit is used (e.g. Hz, kHz), the *step* column is not visible

By clicking on the table header, there is possible to order the rows as per selected column. By clicking the same column again, the user can arrange the rows in ascending or descending order.
Double clicking on a value will place the value into the currently edited row within the Timing values table.

The values listed in the possible settings table depend on the following timing settings:

- prescalers
- minimal timer ticks

and it also depend on

- selected CPU
- selected peripheral
- speed-modes enabled for the component

The table contains a **speed mode tabs** (speed modes and related settings are supported only in the EXPERT view mode) that allow to filter the displayed intervals for a specific speed mode or show intersection of all. Please note that the intersection contains only a values that can be set in all speed modes with absolute precision (without any error), so some values that are still valid due to non-zero *Error allowed* value are not shown.

2.4.3.2. Syntax for the Timing Setup in the Component Inspector

The properties that contain timing settings can be configure using the timing dialog box (For details, please see the chapter *2.4.3.1 Dialog Box for Timing Settings*) or directly by entering the timing value. If the timing values are specified directly, it's necessary to type not only a **value** (integer or real number) but also the **unit** of that value. The following units are supported:

- **microseconds** - A value must be followed by `us`.
- **milliseconds** - A value must be followed by `ms`.
- **seconds** - A value must be followed by `s`.
- **CPU ticks** - A unit derived from the frequency of external clock source. If there is no external clock enabled or available, it is derived from the value of internal clock source. A value must be followed by `ticks`.
- **Hertz** - A value must be followed by `Hz`.
- **kilohertz** - A value must be followed by `kHz`.
- **megahertz** - A value must be followed by `MHz`.
- **bit/second** - A value must be followed by `bits`.
- **kbit/second** - A value must be followed by `kbits`.

Example

If you want to specify 100 milliseconds, enter `100 ms`

For more details on timing configuration, please see the chapter *3.3.4 Timing Settings*.

2.4.4. Configuration Inspector

Configuration Inspector is a variant of an Inspector Window. It shows the settings that belong to one configuration. It could be invoked from configurations pop-up menu in the Project Panel (Click on a configuration with the right button and choose the *Configuration Inspector*). For details on configurations please see the chapter *3.3.2 Configurations*.

Properties

The *Properties* tab contains optimization settings related to the configuration. These setting should be used when the code is already well debugged. They could increase speed of the code, but the generated code is less protected for the unexpected situations and finding errors could be more difficult.

Please note that some of the options may not be present for all Processor Expert versions.

- **Ignore range checking** - This option can disable generation of the code, that provides testing for parameter range. If the option is set to "yes", methods do not return error code ERR_VALUE neither ERR_RANGE. If the method is called with incorrect parameter, it may not work correctly.
- **Ignore enable test** - This option can disable generation of the code, that provides testing if the component/peripheral is internally enabled or not. If the option is set to "yes", methods do not return error code ERR_DISABLED neither ERR_ENABLED. If the method is called in unsupported mode, it may not work correctly.
- **Ignore speed mode test** - This option can disable generation of the code, that provides a testing, if the component is internally supported in the selected speed mode. If the option is set to "yes", methods do not

return error code ERR_SPEED. If the method is called in the speed mode when the component is not supported, it may not work correctly.

- **Use after reset values** - This option allows Processor Expert to use the values of peripheral registers which are declared by a chip manufacturer as the default after reset values. If the option is set to "no", all registers are initialized by a generated code, even if the value after reset is the same as the required initialization value. If the option is set to "yes", the register values same as the after reset values are not initialized.
- **Complete initialization in Peripheral Init. Component** - This option can disable shared initialization peripheral in Init methods of Peripheral Initialization Components. If this option is set to "yes", the complete peripheral initialization is provided in Init method, even for parts that are already initialized in CPU or elsewhere. The could mean longer code, but the initialization can be repeated in application using the Init method.

Comment

The *Comment* tab allows to enter a text that will be shown in the hint when the mouse cursor will be placed on the configuration. It could be any text related to the configuration, for example an explanation of the configuration purpose or some necessary hardware settings.

2.5. Target CPU View

This window displays selected target MCU with its peripherals and pins.

Control Buttons

The meanings of the buttons are:

- **Zoom in** - Increases the detail level of the view. The whole picture might not fit the viewing area.
- **Zoom out** - Decreases the detail level of the view. Processor Expert tries to fit the whole picture to the viewing area.

Pins

The following information about each pin is displayed on the CPU picture:
(all pins are displayed only in the MCU package view mode)

- pin name (default or user-defined)
- icon of a component that uses (allocates) the pin
- direction of the pin (input, output, or input/output) symbolized by blue arrows, if a component is connected

Pin names are shortened and written either from left to right or from top to bottom and are visible only if there is enough space in the diagram.

Some signals and peripherals cannot be used by the user because they are allocated by special devices such as power signals, external or data bus. The special devices are indicated by a special blue icons, for example . The allocation of peripherals by special devices can be influenced by CPU properties.

Hints

Pin hint contains:

- number of the pin (on package)
- both names (default and user-defined)
- owner of the pin (component that allocates it)
- short pin description from CPU database

Component icon hint contains:

- component name
- component type
- component description

Shared Pins

If a pin is shared by multiple components, the line connecting the pin to the component has a red color. See *3.3.8 Pin Sharing* for details.

On-chip Peripherals

The following information about each on-chip peripheral is displayed on the CPU package:

- peripheral device name (default or user-defined)
- icon of the component that uses (allocates) the peripheral device

Peripheral device hint contains:

- peripheral device name
- owner of the pin (component that allocates it)
- short peripheral device description

Hint on icon contains:

- component name
- component type
- component description

If a peripheral is shared by several components (for example: several components may use single pins of the same port), the icon is displayed.

Note for peripherals working in several modes:
Some peripherals work in several modes and these peripherals can be represented by a several devices in the CPU databases. For example, the device "TimerX_PPG" and "TimerX_PWM" represents TimerX in the PPG and PWM mode. These devices can be displayed on the CPU package, but they are also represented as a single block in the MCU block diagram.

Peripheral/Pin Pop-up Menu

The following commands are available in the pop-up menu:

- **Show Peripheral Initialization** - shows initialization values of all "control, status and data" registers. This option is supported for all devices displayed on a CPU package. See *2.7 Peripheral Initialization View* for details.
- **Zoom in** - Increases the detail level of the view. The whole picture might not fit the viewing area.
- **Zoom out** - Decreases the size of the picture and detail level of the view.
- **Rotate** - Rotates the package by 90 degrees.
- **Add Component/Template** - adds a component or template for the appropriate peripheral: all available components and templates suitable for the selected peripheral are listed. The components and templates in the list are divided by a horizontal line. It is possible to add only components or templates which are applicable for the peripheral. It means that is possible to add the component or template only if the peripheral is not already allocated to another component or components. The components/templates that cannot be added to the peripheral are grayed in the pop-up menu as unavailable. This option is supported for all devices displayed on CPU package.

2.6. Memory Map View

This window shows the CPU address space and **internal** and **external memory** mapping. Detailed information for an individual memory area is provided as a hint when the user moves cursor over it.

Legend:

white: non-usable space

dark blue: I/O space

blue: RAM

light blue: ROM, OTP or Firmware

cyan: FLASH memory or EEPROM. This area can also contain a flash configuration registers area.

black: external memory

The address in the diagram is increasing upwards. The sizes of individual memory areas blocks drawn in the window are different from the ratio of their real sizes to improve readability of the information (Small blocks are larger and large blocks are smaller).

The black line-crossed areas show the memory allocated by a component or compiler. The address axis within one memory block goes from the left side to the right (i.e. the left side means start of the block, the right side means the end).

Figure 2.8 - Sample Of Used Part Of The Memory Area

2.7. Peripheral Initialization View

Peripheral Initialization shows overview of the peripheral initialization settings for the current target CPU. It displays initialization values of all *control, status and data* registers of selected peripheral including single bits. The values are grouped into two parts: **Peripheral registers** containing registers directly related to the selected peripheral and **Additional registers** containing the registers that are influenced by the component but are not listed for the peripheral currently selected in this window.

The initialization information reflects:

- MCU default settings - When the peripheral is not utilized by any Embedded Component.
- Embedded Component settings - When the peripheral is utilized by an Embedded Component and the component settings are correct. Peripheral Initialization Inspector shows initialization as required by the component settings.

Register Values Table

The table within the window shows the restisters and their initialization value, displayed in the column *Init. value* . This value written into the register or bit by the generated code during the initialization process of the application. It is the last value that is written by the initialization function to the register. The *After reset* column contains the value that is in the register by default after the reset.

The values of the registers are displayed in the hexadecimal and binary form. In case the value of the register (or bit) is not defined, an interrogation mark "?" is displayed instead of the value.

Note: For some registers, the value read from the register afterwards can be different than the last written value. For example, some interrupt flags are cleared by writing 1. Please see the MCU manual for details on registers behavior.

In case the peripheral is allocated by a component and the setting of the component is incorrect, the initialization values are not displayed in the Peripheral Initialization window.

3. Application Design

This chapter will hep you to design application using Processor Expert and Embedded Components. You will find here recommendations and solutions to write and optimize a code effectively. If you are a beginner, please see the section Quick start that shows how to generate the code of your first project.

The following subchapters explain:

- Quick Start in Processor Expert
- Basic Principles
- Configuring Components
- Implementation Details
- Code Generation and Usage
- Embedded Component Optimizations
- Converting Project to Use Processor Expert
- Low-level Access to Peripherals
- Processor Expert Files and Directories

3.1. Quick Start in Processor Expert

Step 1 - Open an example

You can start learning Processor Expert by opening one of the available examples. Use the command **File > Import...** to open the **Import dialog**. Then select **General / Existing Projects into Workspace** and click **Next** button. All Processor Expert examples can be found within the folder *{CodeWarrior_fo_MCUs}* `\MCU\CodeWarrior_Examples\Processor_Expert`. Use the **Browse** button and select the directory of the example project that you would like to use under this folder. Click on the **Finish** button.

Step 2 - Code generation

After opening an example, invoke the code generation of the project to obtain all sources. In the project tree, right-click the **ProcessorExpert.pe** file and select the **Generate Processor Expert Code** command. The generated code is placed in the *Generated_Code* sub-folder of the project.

Step 3 - More Complicated Example

Once you have learned the basic skills, you can open a more complicated example in order to get to more advanced level of code generation.

Creating New Projects

See the chapter *4 Processor Expert Tutorials* for step-by-step tutorials on creating Processor Expert projects from the beginning.

3.2. Basic Principles

The application created in Processor Expert is built from the building blocks called Embedded Components. The following sub-chapters describe the features of the Embedded Components and the CPU components that are special type of Embedded Components and what they offer to the user.

- Embedded Components
- CPU Components

3.2.1. Embedded Components

Embedded components encapsulate the initialization and functionality of embedded systems basic elements, such as CPU core, CPU on-chip peripherals (for details on categories of components delivered with Processor Expert see chapter *3.2.1.1 Component Categories*), FPGAs, standalone peripherals, virtual devices, and pure software algorithms.
These facilities are interfaced to the user through properties, methods and events. It is very similar to objects in the Object Oriented Programming (OOP) concept.

Easy Initialization

A user can initialize components by setting their initialization properties in the Component Inspector. Processor Expert generates the initialization code for the peripherals according to the properties of the appropriate components. User can decide whether the component will be initialized automatically at startup or manually by calling the component's Init method.

Easy On-chip Peripherals Management

Processor Expert knows exactly the relation between the allocated peripherals and the selected components. When the user selects a peripheral in the component properties, Processor Expert proposes all the possible candidates but signals which peripherals are allocated already (with the icon of the component allocating the peripheral). PE also signalizes peripherals that are not compatible with the current component settings (with a red exclamation mark). In the case of an unrealizable allocation, an error is generated.

Unlike common libraries, Embedded Components are implemented for all possible peripherals, with optimal code. The most important advantages of the generated modules for driving peripherals are that you can:

- Select any peripheral that supports component function and change it whenever you want during design time.
- Be sure that the component setting conforms to peripheral parameters.
- Choose the initialization state of the component.
- Choose which methods you want to use in your code and which event you want to handle.
- Use several components of the same type with optimal code for each component.

The concept of the peripheral allocation generally does not enable sharing of peripherals because it would make the application design too complicated. The only way to share resources is through the components and their methods and events. For example, it is possible to use the RTIshared component for sharing periodic interrupt from timers.

Methods

Methods are interfacing component functionality to user's code. All enabled methods are generated into appropriate component modules during the code generation process. All Methods of each component inserted into the project are visible as a subtree of the components in the Project panel.
You can use in your code all enabled methods. The easiest way to call any method from your code is to drag and drop the method from project panel to the editor. The complexity and number of methods depend on the component's level of abstraction.

Events

Some components allow handling the hardware or software events related to the component. The user can specify the name on function invoked in the case of event occurrence. They are usually invoked from the internal interrupt service routines generated by Processor Expert. If the enabled event handling routine is not already present in the event module then the header and implementation files are updated and an "empty" function (without any code) is inserted. The user can write event handling code into this procedure and this code will not be changed during the next code generation.
All Methods and Events of each component inserted into the project are visible as a subtree of components in the Project panel.

Interrupt Subroutines

Some components, especially the Low-level components and the Peripheral Initialization components (please see more details in chapter *3.2.1.1 Component Categories*) allow to assign an interrupt service routine (ISR) name to a specific interrupt vector setup.
The name of the Interrupt service is generated directly to the interrupt vector table and the user has to do all necessary control registers handling within the user code. See *3.5.3.1 Typical Usage of Peripheral Initialization Components* for details.
ISRs items are listed in the subtree of a component in the Project panel.

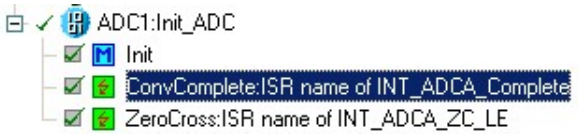


Figure 3.1 - Example Of a Component With Two ISRs

Highly Configurable and Extensible Library

Embedded Components can be created and edited manually or with the help of Component Wizard. CPU Components are a special category of components.

More information about Embedded components can be found in Processor Expert:

3.2.1.1. Component Categories

Components Library Categories

Complete list of the component categories and corresponding components can be found in the Component Categories page of the Components Library

The components are categorized based on their functionality, so you can find an appropriate component for a desired function in the appropriate category. There are the following four main categories, which further contain various sub-categories.

- **CPU** - All available CPU components. The CPU folder in Components Library contains subfolders for the CPU families.
- **CPU External Devices** - Components for devices externally controlled to the CPU. For example sensors, memories, displays or EVM equipment.
- **CPU Internal Peripherals** - Components using any of on-chip peripherals offered by the CPU. The Components Library folder with the same name contains sub-folders for the specific groups of functionality. (i.e. Converters, Timers, PortIO etc.)

  Note: It seems that components (especially in this category) correspond to on-chip peripherals. Even this declaration is close to the true, the main purpose of the component is providing the same interface and functionality for all supported CPU derivatives. This portability is the reason why the component interface often doesn't copy all features of the specific peripheral.

- **SW** - Components encapsulating a pure software algorithms or inheriting a hardware-dependent components for accessing peripherals. These components (along with components created by the user) can be found in a components library in the folder 'SW'.

Specific functionality of the CPU derivative may be supported as a **version-specific** settings of the component. For more information about this feature please refer to *Version specific* parts in the component documentation or Components Implementation help chapter.

Levels of Abstraction

Processor Expert provides components with several levels of abstraction and configuration comfort.

- **LDD components** - Logical Device Drivers. The LDD components are efficient set of components that are ready to be used together with RTOS. They provide a unified hardware access across MCUs allowing to develop simpler and more portable RTOS drivers or bare board application. See *3.2.1.2 Logical Device Drivers* for details.
- **High Level Components** - Components that are the basic set of components designed carefully to provide functionality to most microcontrollers in market. An application built from these components can be easily ported to another microcontroller supported by the Processor Expert. This basic set contains for example components for simple I/O operations (BitIO, BitsIO, ByteIO, ...), timers (EventCounter, TimerInt, FreeCntr, TimerOut, PWM, PPG, Capture, WatchDog,...), communication (AsynchroSerial, SynchroMaster, SynchroSlave, AsynchroMaster, AsynchroSlave, IIC), ADC, internal memories.
  This group of components allows comfortable settings of a desired functionality such as time in ms or frequency in Hz without user knowing about the details of the hardware registers. CPU specific features are supported only as CPU specific settings or methods and are not portable.
  The components inheriting or sharing a high-level component(s) to access hardware are also high-level components.

- **Low Level Components** - Components that are dependent on the peripheral structure to allow the user to benefit from the non-standard features of a peripheral. The level of portability is decreased due to a different component interface and the component is usually implemented only for a CPU family offering the appropriate peripheral. However, you can easily set device features and use effective set of methods and events.
- **Peripheral Initialization Components** - Components that are on the lowest level of abstraction. An interface of such components is based on the set of peripheral control registers. These components cover all features of the peripherals and are designed for initialization of these peripherals. Usually contain only "Init" method, see *3.5.3.1 Typical Usage of Peripheral Initialization Components* for further details). The rest of the function has to be implemented using a low level access to the peripheral. This kind of components could be found in the "**CPU Internal Peripherals / Peripheral Initialization Components**" folder of the Components library and they are available only for some CPU families. The interface of these components might be different for a different CPU. The name of these components starts with the prefix 'Init_'.

Features of Components at Different Level of Abstraction

Feature	LDD components	High level	Low level	Peripheral Init
High-level settings portable between different CPU families	partially	yes	partially	no
Portable method interface for all CPU families	yes	yes	partially (usually direct access to control registers)	*Init* method only
CPU specific peripheral features support	mostly yes	partially	mostly yes	full
Low-level peripheral initialization settings	partially	no	partially	yes
Speed mode independent timing	yes	yes	mostly yes	no
Events support	yes	yes	yes	no (direct interrupt handling)
Software emulation of a component function (if the specific hardware is not present)	no	yes	no	no
Support for RTOS drivers creation	yes	no	no	no

3.2.1.2. Logical Device Drivers

Introduction

Logical Device Drivers were developed to offer users the Hardware Abstraction Layer (HAL) for bare-metal applications as well as RTOS applications. The components provide tested, optimized C code tuned to the application needs. The code may be tuned to the specific RTOS when the RTOS component is in the project.

Differences between LDD and High Level Components

- Each component provides **Init()** method to initialize appropriate peripheral and driver. **Init()** method returns a pointer to driver's device structure.
- Each component provides **Deinit()** method to de-initialize appropriate peripheral and driver.
- The first parameter of each component's method is a pointer to a device structure returned from **Init()** method. It is up to the user to pass a valid device structure pointer to component's methods (null check is highly recommended).
- The **Init()** method has one parameter **UserDataPtr**. A user can pass a pointer to its own data and this pointer is then returned back as a parameter in component's events. The pointer or date pointed by this pointer is not modified by driver itself. A bare-board application typically passes a null pointer to **Init()** method.
- LDD components are not automatically initialized in CPU component. A user must call appropriate **Init()** method during runtime.
- LDD components have RTOS adapter support allowing to generate variable code for different RTOSes.
- Runtime enable/disable of component events.
- Low Power Modes support.

Logical Device Drivers in Bare-metal Applications

Logical Device Drivers can be used in applications where the RTOS is not required.

Logical Device Drivers in bare-metal environment have following specific features:

- **Init()** method of each component uses a static memory allocation of its device structure.
- Interrupt Service Routines are statically allocated in generated interrupt vector table (IVT).
- The Linker Command File (LCF) is generated from CPU component.
- The main module (ProcessorExpert.c) is generated.

Logical Device Drivers in RTOS environment

Logical Device Drivers in RTOS environment have following specific features:

- Init() method of each component uses a dynamic allocation of its device structure through the RTOS API.
- Deinit() method of each component uses a dynamic de-allocation of its device structure through the RTOS API.
- Interrupt Service Routines are allocated through the RTOS API in Init() method and de-allocated in Deinit() method of each component.
- The Interrupt table is not generated from CPU component in case whether RTOS provides runtime allocation of interrupt service routines.
- The Linker Command File (LCF) is not generated from CPU component in case that RTOS provides its own LCF for applications.

- The main module (ProcessorExpert.c) is not generated if specified in RTOS adapter.

For information and hints on LDD components usage, please see the section *3.5.3.2 Typical LDD Components Usage*.

RTOS adapter

The RTOS adapter component is a way how to utilize generated code to the specific RTOS. The RTOS adapter provides necessary information to the driver which API should be used to allocate memory, create a critical section, allocate interrupt vector, etc.

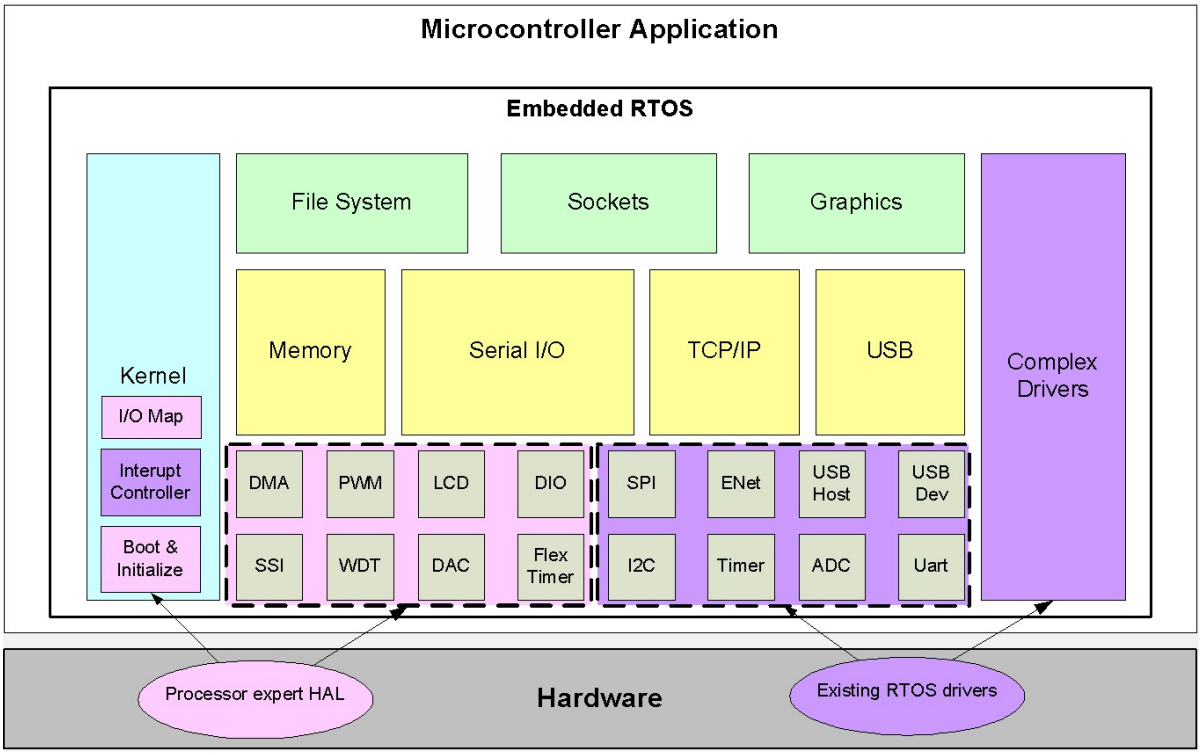


Figure 3.2 - Example of HAL integration into existing RTOS

Shared Drivers

Logical device drivers support the shared mode that means that more components can be put together to provide one instance of API. The user can access each component instance through the API of the shared component. A driver device data structure is used for resolution which peripheral instance shall be accessed. Currently there are three components that support shared mode: Serial_LDD, CAN_LDD and Ethernet_LDD.

Low Power Features

Logical device drivers in conjunction with CPU component implement low power features of a target MCU. Each LDD component define two methods related to the low power capability – **SetOperationMode()** and **GetDriverState()**. For more details see documentation of components.

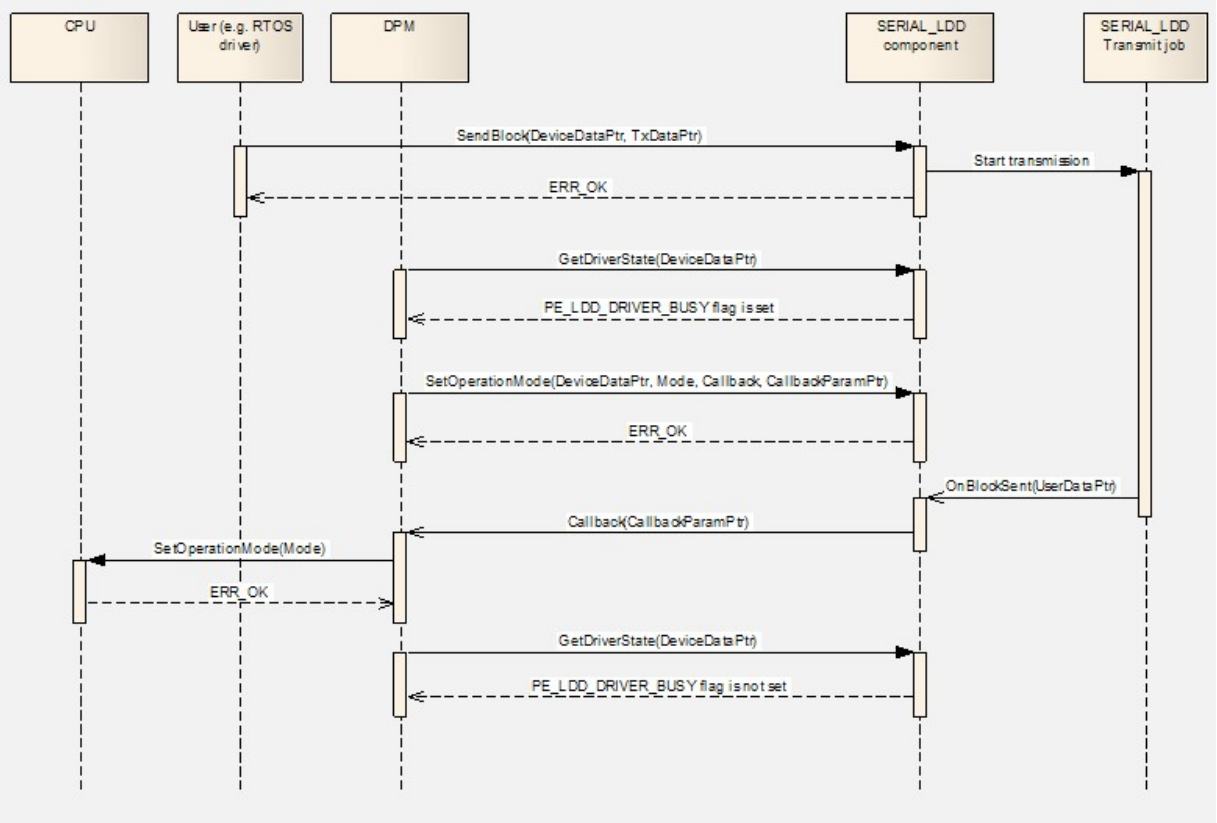


Figure 3.3 - Usage of low power API in Logical Device Drivers

In the example above, DPM (Dynamic Power Manager) task may opt to care for a selected number of peripherals for graceful power mode change (eg. FEC, CAN) and rest of the peripheral drivers need not know the power mode change. When opted for informing a peripheral device driver, the DPM can build a semaphore object for low power acknowledgement from the device drivers. When all such acknowledgements arrive (ie. Semaphore count equals zero) the CPU can be placed into a wait/sleep power mode. In the future, with silicon design modifications, these semaphores can be implemented in the hardware and as a result a much faster power mode change can be expected. In There is no DPM in typical bare-metal applications the DPM task is implemented. In this case DPM is substituted by a user application code.

3.2.2. CPU Components

A CPU component is an Embedded Component encapsulating one CPU type. Like all other components, CPU Components also have properties, methods and events. A Processor Expert project may contain several CPU components. The project generated for one CPU is called an Application. CPUs included in a project are displayed in the upper part of the Project panel (depending on the Project panel settings). Before starting the code generation, one of the CPU components must be active (selected as the **Target CPU**).

The **Build options** accessible in the Component Inspector of the CPU component allow the user to set properties of the **Compiler** and **Debugger** (if it is supported).

Portability

- It is possible to change the target CPU during the development of an application and even to switch between multiple CPUs. This can be done simply by adding another CPU to the project and selecting it as the target CPU.
- To connect the new CPU peripherals to the application components correctly, it is possible to specify the CPU on-chip peripheral names. *This way the same peripheral could be used on different CPU derivatives even if the original name is different.*

Note: CPU peripherals names and Application Options are in the same pop-up menu as CPU inspector. To open the pop-up menu, right-click the CPU icon in the Project panel.

Adding a CPU to a Project.

1. In the Components Library window, select the **MCU** category and find the desired CPU component.
2. Double-click the desired CPU icon to add it to the project. When the CPU component is added, it appears in the upper part of the Project panel. If selected as the target CPU, the processor will be displayed in the Target CPU window.

Selecting a CPU as Target CPU

The first CPU added to the project is automatically selected as the **target CPU**. It means that code will be generated for this CPU. When there are more than one CPU in the project, the target CPU can be changed by following these steps:

1. Right-click the CPU icon in the Project panel to display a pop-up menu.
2. Select **Select CPU as target** - the CPU is selected as target.

This setting doesn't affect the setting of the target in the **Targets** tab in the CodeWarrior project panel. If the user changes the target CPU in the Processor Expert project panel and the CPU doesn't match with the current CodeWarrior target settings, the **Linker dialog box** is invoked during the code generation allowing the user to update the linker setup.

Changing CPU Settings

The only way to modify CPU settings (its properties, methods, events, chip selects, timing, user-reserved peripherals, compiler and debugger settings etc.) is to invoke the Component Inspector for the selected CPU component.

If you have added CPU to your project, you can invoke Component Inspector by performing either of the following:

- Right click the CPU icon in the Project panel to display pop-up menu and select the **CPU inspector**.
- Double-click the CPU icon in the Project panel.

For a detailed description of the current CPU properties, methods and events, select **Help > Help on Component** menu item in the Component Inspector window.

3.2.2.1. CPU Properties Overview

CPU Properties can be set in CPU Component Inspector. The complete list of CPU properties and their description is available in the help page for the CPU. To open the CPU help page, select **Help > Help on Component** from the menu bar in the Component Inspector window.

Following properties define the basic settings of the CPU:

- CPU type
- External Xtal frequency (and sub-clock xtal frequency)
- PLL settings
- Initialization interrupt priority
- External bus and signals
- Speed modes (See the following chapter Speed Modes).
- All other functions that are not directly encapsulated by components

3.2.2.2. Speed Modes Support

Note: Register access macros are not available for Kinetis family MCUs. Please use the Clock configurations instead.

The CPU component supports up to three different **speed modes**. The three **speed modes** is a Processor Expert specific concept which (among all the other PE features and concepts) ensures the portability of the PE projects between different CPU models.

In fact, the three speed modes are a generalization of all the possible CPU clock speed modes used for power-saving that can be found in most of the modern microcontrollers. In the area of embedded systems, power saving and power management functions are so important that we could not neglect the proper HW- independent software implementation of these functions.
Therefore, for keeping the portability (HW independence) of PE projects, we recommend not to program the CPU speed functions manually, but use these three CPU Component speed modes instead:

- **High speed mode** - this mode is selected after reset and must be enabled in the project. This speed mode must be the fastest mode of the main CPU clock.
- **Low speed mode** - this mode is usually used for another PLL or main prescaler settings of the main CPU clock.
- **Slow speed mode** - this mode is usually used for the slowest possible mode of the main CPU clock.

Switching Speed Modes at Runtime

The modes can be switched in the runtime by the following **CPU component methods**:

- SetHighSpeed
- SetLowSpeed
- SetSlowSpeed

If a speed mode is enabled in the CPU Component properties, the corresponding method is enabled automatically.

It is highly recommended to disable interrupts before switching to another speed mode and enable them

afterwards.

Speed Modes Support in Components

Using the component property *CPU clock/speed selection*, it is possible to define the speed modes supported by the component.
Some components allow to set two values of the *CPU clock/speed selection* property:

- *Supported* - The *CPU clock/speed selection* group contains properties defining which speed modes are supported for the component.
- *Ignored* - The speed mode settings are ignored and there are no action is performed when a speed mode is changed, that is the peripheral continues to run with the same configuration for all speed modes. No speed mode handling code is generated for this component. The component timing values are valid only for high-speed mode.

The following features are available for high-level components, if the *CPU clock/speed selection* is not set to *ignored*:

- During the design, all the timing-related settings for such a component are checked to be correct in all the speed modes that the component supports and the component is enabled in these modes.
- If the speed mode is changed, the current timing components are preserved (recalculated to be the same in the new speed mode), except the timing that is set at runtime from interval.
  If the CPU speed mode is changed to a mode that the component does not support for any reason, the component is disabled right after the CPU speed mode is changed. Otherwise the component is enabled.
- Before or after the speed mode is changed, the *BeforeNewSpeed and AfterNewSpeed* event functions are called.

3.3. Configuring Components

Configuring the components in the project is one of the main activities in Processor Expert. It affects the initialization, run-time behavior and range of functionality available to the user of the generated code. For the description of the user interface of the components settings please see the chapters *2.2 Project Panel View* and *2.4.3 Component Inspector*.

The following sub-chapters provide hints and information about how to configure the Embedded Components used in the project correctly and effectively.

- Interrupts and Events
- Configurations
- Design Time Checking: Consequences and Benefits
- Timing Settings
- Creating User Component Templates
- Signal Names
- Component Inheritance and Component Sharing
- Pin Sharing

3.3.1. Interrupts and Events

This chapter describes the details of interrupt and events processing in the code generated by Processor Expert.

An **Interrupt** is a signal that causes the CPU stop the execution of the code and execute the Interrupt service routine instead. When the execution of the code is suspended, the current state of the CPU core is saved on the stack. After the execution finishes, the previous state of the CPU core is restored from the stack and the suspended program continues from the point where it was interrupted. The signals causing interrupts can be hardware events or software commands. For more details, please see an appropriate CPU manual.
Each interrupt can have an assigned **Interrupt Service Routine** (ISR) that is called when the interrupt occurs. The table assigning the subroutines to interrupts is called **Interrupt Vector Table** and it is completely generated by Processor Expert. Most of the interrupts have corresponding Processor Expert Events that allow handling of these interrupts. Processor Expert also allows to configure interrupt priorities, if they are supported by the CPU. See *3.3.1.1 Processor Expert Priority System* for details.

Processor Expert **Events** are part of the Embedded component interface and encapsulate the hardware or software events within the system. Events are offered by the High and Low Level components to help the user to service the events without any knowledge of the platform specific code required for such service.

Processor Expert **Events** can be enabled and disabled and have a user-written program subroutines that are invoked when the event occurs. Events often correspond to interrupts and are for that case invoked from the generated ISR. Moreover, the event can also be a pure software event caused by a buffer overflow or improper method parameter.

Interrupts Usage in Component's Generated Code

Some high-level components use interrupt service routines to provide their functionality. Usage of interrupts can usually be enabled/disabled through property "Interrupt service/event". If the interrupt service is used, complete interrupt service routine is generated into component's driver and the generated code contains configuration of the corresponding peripheral to invoke the interrupts.

The user should be careful while disabling an interrupt. If a component should operate properly, it is necessary to allow the interrupt invocation by having interrupts enabled and (if the CPU contains priority system) set the corresponding interrupt priority level. This can be done using the appropriate method of the CPU component.

Note: It is a common "bug" in user code, if the application is a waiting for a result of the component action while the interrupts are disabled. In this situation, the result of the component method does not change until the interrupt service routine is handled. See description of the property "Interrupt service/event" for detailed information about the particular component.

Enabling Event

Functionality of each event can be enabled or disabled. The user can easily enable the event and define its name within the Component Inspector of the appropriate component. Another possibility is to double-click an event icon in the component's subtree or use a pop-up menu in the Project Panel window.

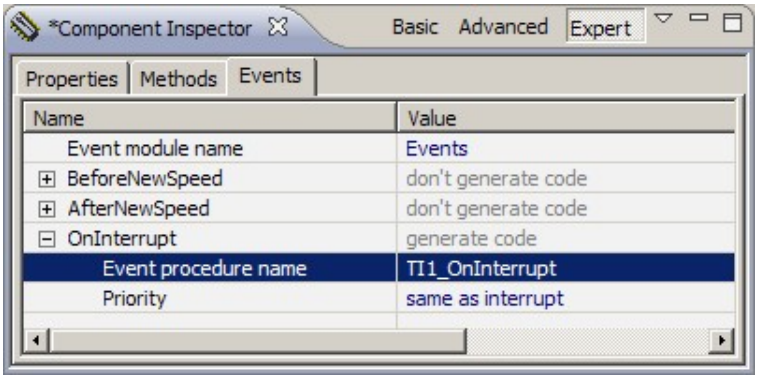


Figure 3.4 - Event Example in the Component Inspector Events Tab

Writing an Event Handler

Event handler is a subroutine that is assigned to a specific event. After the event is enabled Processor Expert generates the empty function of the specified name to the Event module. See *3.5.1 Code Generation* for details. The user can directly open the Event handler code (if it already exists) using a **Component pop-up menu > View/Edit event module** or a double-click on the event within the Project Panel. The event handler is an ordinary function and the user needs not to provide the interrupt handling specific code in his/her event code.

Interrupt Service Routines

When **High or Low-level components** are used, the interrupts functionality is covered by the events of the components. The interrupt subroutines calling the user's event handlers are generated to the component modules and PE provides parts of the background code necessary to correctly handle the interrupt requests.

The **Peripheral Initialization components** can only provide the initialization of the interrupt and generate a record to the Interrupt Vector Table. The user has to provide a full implementation of the interrupt subroutine. See *3.5.3.1 Typical Usage of Peripheral Initialization Components* for details.

3.3.1.1. Processor Expert Priority System

Some CPUs support selectable **interrupts priorities**. The user may select a priority for each interrupt vector. The interrupt with a higher priority number can interrupt a service routine with the lower one.

Processor Expert supports the following settings in design-time: interrupt priority and priority of the event code. Priority can also be changed in the user code. The user may use a CPU component method to adjust the priority to a requested value.

Interrupt Priority

The user may select interrupt priority in the component properties, just below the interrupt vector name. Processor Expert offers the following values, which are supported for all microcontrollers:

- **minimum priority**
- **low priority**
- **medium priority**
- **high priority**
- **maximum priority**

The selected value is automatically mapped to the priority supported by the target microcontroller. It is indicated

in the third column of the Component Inspector.
The user may also select a target-specific numeric value (such as priority 255), if portability of the application to another architecture is not required.
Peripheral Initialization components on some platforms also allow to set the value **default** that means that the user doesn't have any requirement on it so the priority value will be the default after-reset value.

Version specific information for HCS08 derivatives with IPC (Interrupt Priority Controller)
The HCS08 derivatives with IPC module offer an interrupt priority configuration. There are four interrupt priority levels 0 to 3 available, where 0 is the lowest priority and 3 is the highest one.
The platform-independent interrupt priority values in Processor Expert described on top of this section are mapped to these values.

Version specific information for RS08 without interrupt support and HC(S)08 derivatives without IPC (Interrupt Priority Controller)
These derivatives do not support interrupt priorities. The interrupt priority settings, for example imported from a project for another CPU, are ignored.

Version specific information for RS08 with interrupt support
On these RS08 derivatives, the interrupts are handled through single interrupt vector. The priority of each individual "emulated interrupt" is determined by order in which the SIPx registers are polled in the sofware handler. The priority can be in the range 0 ..number_of_interrupts-1 (e.g. 0 .. 15). The lower is the number the higher is the priority. The platform independent interrupt priority values in Processor Expert described on top of this section are mapped to these values.
The default priority depends on the position of an associated bit in a SIPx register. The interrupt priority can be changed to any value within the allowed range. Interrupts with lower priority number (higher priority of execution) are polled first. If two interrupts have assigned the same priority number then the order in which they are polled depends on the default priority. For more details on interrupts on RS08 please see the chapter Version Specific Information for RS08.

Version specific information for ColdFire V1 derivatives
On the ColdFire V1 platform, an interrupt priority of an interrupt is determined by an Interrupt Level (1-7) and a Priority within Level (0-7). Please see the CPU data sheet for interrupt priority system details.

The applied interrupt priority value (the value displayed in the third column of the Component Inspector) contains both values - e.g. Level 4, priority within level 6. The target-independent values of interrupt priority (e.g. minimum, maximum etc...) are mapped either to the default priority of the selected interrupt or to Level 6, Priority within level 6 or level 6, Priority within level 7.

Priority of Event Code

Version specific information for Kinetis derivatives
Priority of event code is not supported on this family.

The user can also select a priority for the processing of the event code. This setting is available for the events that are invoked from the Interrupt Service Routines. This priority may be different from the interrupt priority. However, the meaning of the number is the same - the event may be interrupted only by the interrupts with the higher priority. Processor Expert offers the following architecture independent values:

- **same as interrupt** - default value which means that Processor Expert doesn't generate any code affecting the priority of the event - the priority is in the state determined by the default hardware behavior.
- **minimum priority**
- **low priority**
- **medium priority**
- **high priority**
- **maximum priority**
- **interrupts disabled** - *For example the highest priority supported by the microcontroller, which may be interrupted only by non-maskable interrupts.*

The selected value is automatically mapped to the priority supported by the target microcontroller and the selected value is displayed in the third column of the Component Inspector.
Please see version specific information below. The user may also select a target-specific value, if portability of the application to another architecture is not required.

Note: Some events do not support priorities, because their invocation is not caused by the interrupt processing.

Warning: *Please note that Processor Expert does not allow the user decrease an event code priority (with the exception of 'Interrupts enabled' value on some platforms, please see below). This is because Processor Expert event routines are not generally reentrant so there is a risk that the interrupt would be able to interrupt itself during the processing. If there is such functionality requested, the user has to do it manually (e.g. by calling a appropriate CPU component method setting a priority) and carefully check possible problems.*

Version specific information for HCS08 derivatives with IPC (Interrupt Priority Controller)
Processor Expert offers the following event priority options:

- **interrupts enabled** - Interrupts are enabled and the priority of the event routine stays at the same level as the interrupt. The interrupts with the higher priority than the current interrupt priority can interrupt the event code.
- **interrupts disabled** - All maskable interrupts are disabled.
- **1..3** - Priorities from lowest (1) to highest (3). The code generated by Processor Expert before the event invocation sets the event code priority to the specified value.
- **4** - Same as 'interrupts disabled'
- **same as interrupt** - Default behavior of the architecture - no interrupts can interrupt the event. It is same as *interrupts disabled*.
- Other values are mapped to the priorities 1..4.

Version specific information for HC(S)08 derivatives without IPC (Interrupt Priority Controller)
Processor Expert offers the following event priority options:

- **interrupts disabled** - All maskable interrupts are disabled.
- **interrupts enabled** - All maskable interrupts are enabled. Please note that this settings might lead to possible problems, see the warning within this chapter.
- **same as interrupt** - Default behavior of the architecture - no interrupts can interrupt the event. It is same as "interrupts disabled".

Version specific information for RS08 with interrupt support
Because of architecture limitations, the Processor Expert allows only **interrupts disabled** value so the interrupt is always disabled within the event routines. The **same as interrupt** value is mapped to **interrupts disabled**.

Version specific information for ColdFire V1 derivatives
Processor Expert offers the following event priority options:

- **interrupts disabled** - All maskable interrupts are disabled within the event routine.
- **0..7** - Priorities from the lowest (0) to the highest (7). The code generated by Processor Expert before the event invocation sets interrupt priority mask to the specified value. The event routine may be then interrupted only by an interrupt with higher priority than the specified number.
- **same as interrupt** - The priority of the event routine stays on the level set for the interrupt. The event routine can be interrupted only by a higher priority interrupt then the value set for the interrupt.

3.3.2. Configurations

The user can have several configurations of the project in one project file. The configuration system is very simple. Every configuration keeps the **enable/disable state of all components** in the project (it does NOT keep any component settings!). If you enable/disable a component in the project, the component state is updated in the currently selected configuration. If you create a new configuration the current project state is memorized.

Configurations of the current project are listed in the Project Panel configurations folder.

Configurations can also hold additional settings that may influence code generation can be changed in the configuration inspector. See *2.4.4 Configuration Inspector* for details.

The symbol for conditional compilation is defined if it is supported by the selected language/compiler. The symbol **PEcfg_*[ConfigurationName]*** is defined in the CPU interface.
The user can switch using this symbol between variants of code according to the active configuration (see example in this chapter).

Configuration also stores which CPU is selected as the target CPU.
If the name of the configuration matches the name of one of the CodeWarrior's targets, the target is automatically selected as an active target when the user runs code generation.

Note: It is possible to have two components with the same name in Project. Each of the components could be enabled in different configuration. This way the user can have different setup of a component (a component with the same name) in multiple configurations.

Example

Suppose, there is a configuration named 'Testing case'. We use a component and part of our code using the component only in the 'Testing case' configuration. Then we make the testing case configuration active. After the successful code generation the CPU.H file contains the following definition:

```
/* Active configuration define symbol */
#define PEcfg_Testingcase 1
```

The parts of the code intended to be used only in this configuration need to be surrounded with the following lines:

```
...
#ifdef PEcfg_TestingCase
   Component_MethodCall(...);
#endif
...
```

3.3.3. Design Time Checking: Consequences and Benefits

During the design time, Processor Expert performs instant checking of the project. As a result of this checking, error messages may appear in the Error Window or directly in the third column of the Component Inspector (on the faulty items line). Sometimes, it may happen that only one small change in the project causes several (general) error messages. The most common reasons for this behavior are stated below.

On-Chip Peripherals

Some components use on-chip peripherals. In the Component Inspector, you can choose from all possible peripherals that can be used for implementation of the function of the current component. Processor Expert provides checking for required peripheral features such as word width and stop bit for serial channel, pull resistor for I/O pin and others.
Processor Expert also protects against the use of one peripheral in two components. If the peripheral is allocated for one component then the settings of this peripheral cannot be changed by any other component. **The state of an allocated peripheral should never be changed directly in the user code. (Using special registers, I/O ports etc.) It is recommended to always use methods generated by Processor Expert.**

Note that if a peripheral is allocated to any component, all its parts are reserved. For example if you use the 8-bit I/O port, all the I/O pins of the port are allocated and it is not possible to use them in other components.
In some timer components you can choose if you want to use only a part of the timer (compare register) or an entire timer. If you select the entire timer, the driver can be optimized to work best with the timer. It can, for example, invoke reset of the timer whenever is it needed by the component function.

Interrupt Priority

If the target CPU shares interrupt priority between several interrupt vectors or shares interrupt vectors, Processor Expert provides checking of interrupt priority settings. For detailed information about Interrupt Priority see the Priorities page.

Memory

Processor Expert always checks the usage of the internal and external memories accessible throught CPU address and data bus. Position and size of internal memory is defined by the CPU type and can be configured in the CPU Properties (if supported). External memories must be defined in CPU Properties.
Any component can allocate a specified type of memory. See component descriptions for detailed information about requirements for types of memory. Processor Expert provides checking of memory and protects you from making a wrong choice. (*For example: if a component requires external Flash, it is not possible to enter an address in internal RAM*).

The bits can also allocate memory. Therefore, you can be sure that only one component uses an allocated bit of a register in external address space.

Timing

The settings of all timed high-level components are checked using the internal timing model. See *3.3.4 Timing Settings* for details. If there is no error reported, it means that Processor Expert was successful in calculating the initialization and runtime control values for all components and hence the settings should work according to the configuration.

3.3.4. Timing Settings

Many high-level components contain a timing configuration (e.g. speed of the serial communication, period of the interrupt, conversion time of the ADC etc.). Processor Expert allows to configure such timing using user-friendly units and it also contains a model of the complete MCU timing. This model allows calculation of the required values of control registers and continuous validation of the timing settings.

Timing Model

A component timing can be viewed like a chain of elements, such as dividers and multipliers between the main clock source and the device configured by the component. The user sets the desired timing value using the Timing Dialog box (see chapter *2.4.3.1 Dialog Box for Timing Settings*) or directly by specifying the value in Component Inspector (see chapter *2.4.3.2 Syntax for the Timing Setup in the Component Inspector*). Processor Expert tries to configure individual elements in the timing chain to achieve the result and the user is informed if it was successful. After leaving the Timing Dialog box, the real value of the prescaler and timing are shown in the **third column of the component inspector**.

Figure 3.5 - Example of the timing and prescaler setup

Timing Setup Problems

The errors are reported in red in the Timing Dialog box or in the timing property line in the Component Inspector. The error summary is available in the Error window. Please follow the error message text to find the source of the problem. If no error is reported, it means that Processor Expert can achieve the desired timing for all components in the project.

Common problems that make impossible to set a timing value:

- *It is impossible to set some item(s).*
  This problem is reported in the component or the Timing dialog box and the user is informed which value has incorrect value. The reason is usually the hardware structure and limitations of the CPU. The Timing dialog box shows the list of values (ranges) that are allowed to be set. It might be necessary to increase the allowed error (using the 'Error' field in the Timing Dialog) that specifies the allowed difference between the required value and possible value that can be produced by the hardware.
- *Settings for the device are mutually incompatible (or can't be used with another device).*
  In this case, the problem is reported by all components that share some timing hardware. Due to dependencies between used parts of the timer, there might be necessary to adjust the values of the shared elements (such as prescalers) to the same value.
  For example, if two TimerInt components are using two channels of one timer and all timer channels are connected to one common prescaler, it is not possible to set the values that would require a different prescaler values. In this case it is useful to manually adjust the prescaler values of all components to the same value (switch to Expert view mode and adjust the property in the Component Inspector window).
- *The Runtime setting from interval is selected and it is not possible to set the values.*
  The required run-time settings are outside the range of one prescaler. This is a limitation of this mode of runtime setting. Please see the text below in this chapter.

Run-time Timing Settings Limitation

Some components allow to change the timing at run-time by switching among several predefined values or by setting a value from given interval.
For the runtime setting *from interval* the prescaler value is fixed and the Processor Expert allows to adjust the time using a compare/reload registers. **It means that Processor Expert allows to configure the limits of an interval only within a range of one prescaler and it's possible to set values from this interval only.** See *2.4.3.1 Dialog Box for Timing Settings* for details.

Speed Modes

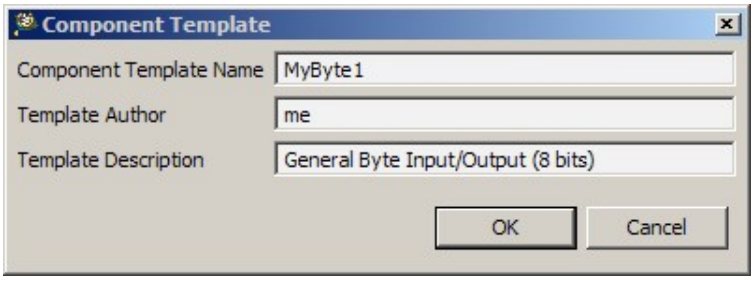
Processor Expert provides three speed modes that are generalization of all the possible CPU clock speed modes used for power-saving supported by most of the modern microcontrollers. See *3.2.2.2 Speed Modes Support* for details.

3.3.5. Creating User Component Templates

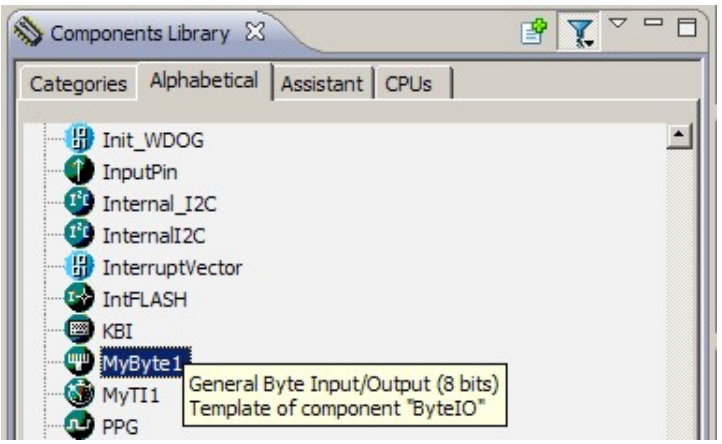
If you frequently use a component with the same specific settings, you may need to save the component with its settings as a template. This template is displayed in the Components library under given name, **behaves as a normal component** and could be added to any project. The template has the same properties as the original component. The values of the properties are preset in the template and could be marked as read only.
This section describes how to create a component template and save it.

Creating and Saving Templates

1. Open the pop-up menu of the component in the Project Panel and select **Save component settings as template**.
   *Alternatively, you can use the Component Inspector window: open the view menu using the arrow icon in the top right corner and select **Save component settings as template**.*
2. Fill in the template details into the dialog box and confirm:



3. The template appears within the Components Library and can be inserted into projects. *It may be necessary to invoke refresh command by selecting the Components Library pop-up menu > Refresh.*



3.3.6. Signal Names

The main purpose of signals is to allow the user to name the pins used by components with names corresponding to the application.

Assigning Signals to Pins

A signal name can be assigned to an allocated pin by specifying the signal name into the appropriate property (e.g. Pin_signal) in the Component Properties (available in ADVANCED view mode). **Signal name is an identifier that must start with a letter and rest of the name must contain only letters, numbers, and underscore characters.**
For the components that allocate a whole port, such as ByteIO, there are two options:

- Assign a same signal name to all pins of port by writing the name into the *Port signal* property. Processor Expert automatically assigns this name extended with a bit number suffix to each of the individual pins.
- Assign a different signal names to individual pins by writing pin signal names (from the lowest bit to the highest one) separated by commas or spaces into the *Port signal* property.

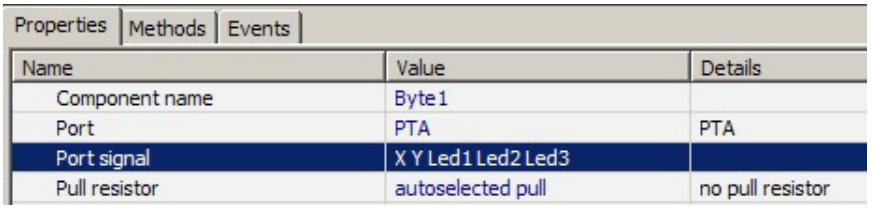


Figure 3.8 - Signal names list for a port

Generated Documenation

Processor Expert automatically generates a document *{projectname}_SIGNALS.txt* or *{projectname}_SIGNALS.doc* containing a list of relationship between defined signals and corresponding pins and vice versa. There is an additional signal direction information added next to each signal name and pin number information next to each pin name. This document can be found in the *Documentation* folder of the Project Panel.

Sample of generated signals documentation:

```
============================================================
 SIGNAL LIST
------------------------------------------------------------
SIGNAL-NAME [DIR]        => PIN-NAME [PIN-NUMBER]
------------------------------------------------------------
LED1 [Output]            => GPIOA8_A0 [138]
LED2 [Output]            => GPIOA9_A1 [10]
Sensor [Input]           => GPIOC5_TA1_PHASEB0 [140]
TestPin [I/O]            => GPIOE0_TxD0 [4]
Timer [Output]           => GPIOC4_TA0_PHASEA0 [139]
============================================================


============================================================
 PIN LIST
```

```
-------------------------------------------------------------
PIN-NAME [PIN-NUM]       => SIGNAL-NAME [DIRECTION]
-------------------------------------------------------------
GPIOA8_A0 [138]          => LED1 [Output]
GPIOA9_A1 [10]           => LED2 [Output]
GPIOC4_TA0_PHASEA0 [139] => Timer [Output]
GPIOC5_TA1_PHASEB0 [140] => Sensor [Input]
GPIOE0_TxD0 [4]          => TestPin [I/O]
=============================================================
```

3.3.7. Component Inheritance and Component Sharing

Basic Terms

- Ancestor is a component that is inherited (used) by another component.
- Descendant is a new component that inherits (uses) another component(s).
- Shared Ancestor is a component that can be used and shared by multiple components.

Inheritance

Inheritance means that an ancestor component is used only by the descendant component. Inheritance is supported in order to allow components to access peripherals by hardware-independent interface of the ancestor components.
For example, a component that emulates a simple I2C transmitter may inherit two BitIO components for generation of an output signal.

On several complex components (for example some MPC5500 Peripheral Initialization components) inheritance is used to separate component settings into several logical parts, for example settings of channel is inherited in the component with settings of the main peripheral module.

Settings in Processor Expert

The Descendant component contains a property that allows selecting an ancestor component from a predefined list of templates. The component is created after selection of an appropriate template name (or component name) from the list of the templates fitting the specified interface. Any previously used ancestor component is discarded.

Figure 3.9 - Inherited component item in inspector.

Clicking on the button unfolds the properties of the inherited component directly under the intherited component property line.
Clicking on the button fully opens the ancestor component with properties, methods, and events within the Component inspector.
Processor Expert allows the user to select from several ancestors that implement a required interface and are registered by the descendant component.
The ancestor component is displayed under its descendant in the project structure tree in the project panel.

Figure 3.10 - Example of ancestor and descendant components in the project panel tree.

An ancestor component requires a list of methods and events (interface), which must be implemented by an ancestor component. The error is shown if the ancestor component does not implement any of them. For example, if the settings of the descendant component do not allow it to generate this method.

Component Sharing

Component sharing allows the user to cause several components to use capability of one component with the way similar to inheritance. This feature allows sharing of its resources and its drivers with other Components.
For example, components may share an I2C component for communication with peripherals connected to the I2C bus.

Settings in Processor Expert

A shared ancestor component contains a property that allows the user to select existing shared ancestor component or create a new one. In this case, the ancestor component is included in the project tree as the other components. The ancestor component may be used with the descendant component only if it is created from a template registered in the descendant component or if the component type is registered in the descendant component. It is recommended that you always create a shared ancestor component through a descendant component.
Click the button to select an existing shared ancestor component from the current project. Click the button to select an existing ancestor component or create a new ancestor component using the wizard (see below).

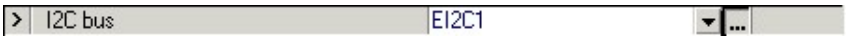


Figure 3.11 - Example of popup menu for creating a new shared ancestor component.

Selection/Creation Wizard

When a component with a link to a shared ancestor component is added to the project, the following wizard dialog box appears. This wizard helps you to select or create the shared ancestor component quickly.

Processor Expert helps you to select or create a shared bean ...
The bean "I2CI2CI2CI2C" uses shared bean for item "I2C bus".
You may choose existing or create new appropriate bean just now.
Use existing bean: EI2C1
Create new bean from template: External_I2C
OK
Cancel
Help

Figure 3.12 - Example of popup menu for creating new shared ancestor component.

Run-time Resources Allocation

Processor Expert (generated code) does not check the usage of shared resources/code. It's up to the user to ensure the correct run-time resources allocation of a shared ancestor component. Often, it is not possible for a shared ancestor component to be used simultaneously by several components.

3.3.8. Pin Sharing

Reading a Pin Value without its Initialization

Note: InputPin component is not available in this version.

The **InputPin** component supports reading of input pin signal without any previous pin initialization. The feature can be used only if the pin (port) contains RAW DATA register, which allows reading the input pin signal in any settings of the related peripherals. See the component documentation for more details.

Sharing Pins among Peripherals

Some CPUs allows some pins to be used by multiple peripherals. This may lead to the need of sharing pin(s) by multiple components. Normally, if the user selects one pin in more than one component, a conflict is reported. However, it is possible to setup a sharing for such pin in the component inspector.

One of the components sharing a pin has to be chosen as a "main component". This component will initialize the pin. In the properties of other components that use the pin, the pin has to be marked as shared by clicking the sharing icon on the right side (see the picture below).

Pin sharing can be set in the component inspector. The Component Inspector must be switched into the **EXPERT view mode**, and then the pin sharing button must be pressed down. The figure below displays the Pin Sharing button at the right side of the second column.

Figure 3.13 - Pin Sharing Button

Pin sharing is advanced usage of the CPU peripherals and should be done only by skilled users. Pin sharing allows advanced usage of the pins even on small CPU packages and allows application-specific usage of the pins.

ConnectPin Method

It's necessary to invoke the component method *ConnectPin* to connect a component to the shared pin. It's also necessary to invoke the main component method to connect pin back to the main component. In fact, the peripherals can usually operate simultaneously, but they have no connection to the shared pins unless the *ConnectPin* method is executed. In case that all components control the shared pin using one peripheral, it's not necessary to use the *ConnectPin* method.

Shared pins are presented in the Target CPU view as well. The component to pin connection line is red.

3.4. Implementation Details

This chapter contains implementation details for Embedded Components and Processor Expert generated code. The following subchapters describe:

- Reset Scenario with PE for HC(S)08 and RS08
- Reset Scenario with PE for ColdFire and Kinetis MCUs
- Version Specific Information for Freescale HC(S)08 and ColdFire V1 derivatives
- Version Specific Information for RS08
- Version Specific Information for Kinetis

Additional implementation specific information can be found on individual component documentation pages.

3.4.1. Reset Scenario with PE for HC(S)08 and RS08

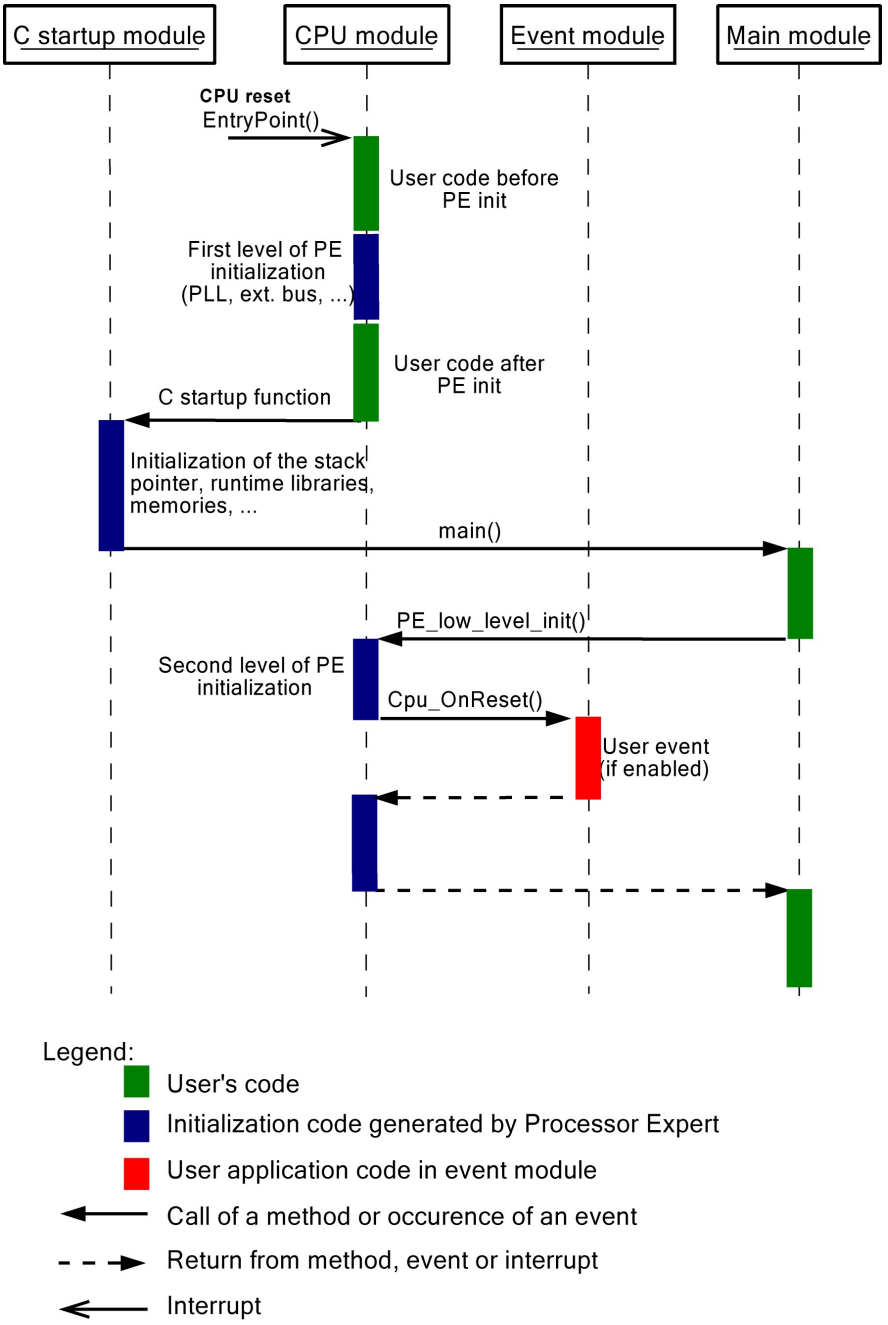


Figure 3.14 - Reset sequence diagram with Processor Expert

_EntryPoint function

The *_EntryPoint()* function is called as the first function after the reset. This function is defined in the cpu module, usually *Cpu.c*, and provides necessary system initialization such as PLL and external bus.

Sometimes it is necessary to do some special user initialization immediately after the cpu reset. Processor Expert provides a possibility to **insert user code into the *_EntryPoint()* function**. There is a *User Initialization property* in the build options tab of a CPU component inspector defined for this purpose. See *2.4.3 Component Inspector* for details.

C startup function

The C startup function in the C startup module is called at the end of the *_EntryPoint()* function. It provides a necessary initialization of the stack pointer, runtime libraries, and so on. At the end of the C startup function the *main()* function is called.

PE_low_level_init()

There is a second level of Processor Expert initialization *PE_low_level_init()* called at the beginning of the *main()* function. *PE_low_level_init()* function provides initialization of all components in project and it is necessary for proper functionality of the Processor Expert project.

OnReset event

The user can write the code that will be invoked from the PE_low_level_init() function after the Processor Expert internal initialization, but before the initialization of individual components. Thus, the user should expect that peripherals are not completely initialized yet. This event can be enabled/disabled in the CPU component inspector's events page.

3.4.2. Reset Scenario with PE for ColdFire and Kinetis MCUs

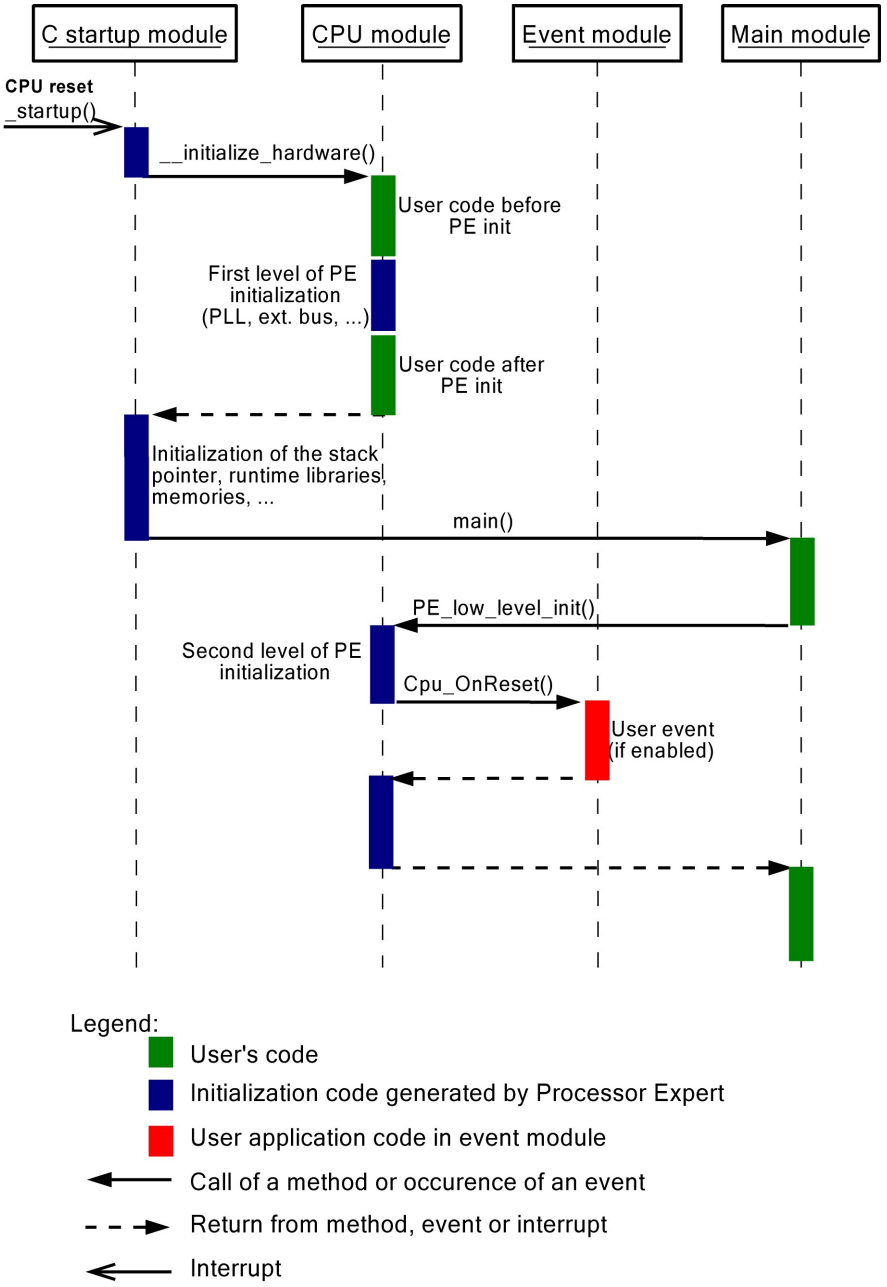


Figure 3.15 - Reset sequence diagram with Processor Expert

_startup()

The *_startup()* function is called as the first function after the reset. The *_startup()* function initializes the stack pointer, calls the *__initialize_hardware()* function and continues with initialization of the enviroment (such as memory initialization). At the end of the *_startup()* function the *main()* function is called.

__initialize_hardware()

The *__initialize_hardware()* function is called from the *_startup* function after an initialization of the stack pointer. This function is defined in the cpu module, usually Cpu.c, and provides necessary system initialization such as PLL, and external bus.
Sometimes it is necessary to do some special user initialization immediately after the cpu reset. Processor Expert provides a possibility to insert user code into the *__initialize_hardware()* function. There is a User Initialization property in the build options tab of a CPU component inspector defined for this purpose. See chapter Component Inspector for details. See *2.4.3 Component Inspector* for details.

PE_low_level_init()

There is a second level of Processor Expert initialization *PE_low_level_init()* called at the beginning of the *main()* function. *PE_low_level_init()* function provides initialization of all components in project and it is necessary for proper functionality of the Processor Expert project.

OnReset event

The user can write the code that will be invoked from the PE_low_level_init() function after Processor Expert internal initialization, but before the initialization of individual components. Thus, the user should expect that peripherals are not completely initialized yet. This event can be enabled/disabled in the CPU component inspector's events page.

3.4.3. Version Specific Information for Freescale HC(S)08 and ColdFire V1 derivatives

The ROM, Z_RAM and RAM ranges depend on the target MCU. It is recommended to increase the stack size if some standard libraries are used.

For the detailed information on debugging HC08 application using **MON8** interface please refer to chapter *3.4.3.2 Debugging on HC08 Using MON8*.

Components' implementation details:

- **All the components**:
  Interrupts priorities - For details on priority settings for interrupts and event please see also *3.3.1.1 Processor Expert Priority System*.

- **CPU**:
  - *Speed Mode* selection (CPU methods *SetHighSpeed*, *SetLowSpeed*, *SetSlowSpeed*): If CPU clock-dependent components are used, the signals generated from such internal peripherals may be corrupted at the moment of the speed mode selection (if function of clocked devices is enabled). Handling of such a situation may be done using events **BeforeNewSpeed** and **AfterNewSpeed**.
  - *Interrupt vector table in ROM is placed* at the default address in the ROM or in the Flash:
    If the *interrupt vector table in RAM* is selected, the vectors table is generated into RAM and special redirection code is generated to ROM. This code transfers program control to the selected address according to the table in RAM. The user can use CPU methods SetIntVect to set the address of interrupt service routine.
    Note: You cannot change the interrupt vector that is allocated by any component in your project. It is recommended to select the event OnSWI together with this option to minimize size of the generated code.

- **PPG**: The PPG components always allocates the whole timer. Although it is technically possible to share the

selected timer between 2 PPG components, it would be impossible to set the PPG period for such two components separately. More information about this component can be found in chapter Timers.

- **PWM**: In contrast to the PPG components, it is possible for the PWM components to share the selected timer, since they do not have the *SetPeriod* method. More information about this component can be found in chapter Timers.
- **EventCntr16**: Since the timer overflow flag is set when the timer reaches a value of 65535, the maximum number of events that can be counted by this component is limited to 65534 (value of 65535 is marked as invalid as the method *GetNumEvents* returns the ERR_OVERFLOW value as its result). More information about this component can be found in chapter Timers
- **TimeDate**: It is recommended to make a setting close to 10 ms (resolution provided by GetTime/SetTime methods). Smaller values unnecessarily overload the system.
- **WatchDog** : When the Watchdog component is added to the project, it is automatically enabled. The enabling code is placed in the CPU initialization code.
  Note: Watchdog is enabled by a write to the configuration register. This register can be written only once after CPU reset. Since the register also contains other bits that are written during the CPU initialization, the watchdog must be enabled when CPU is initialized. The property "CPU clock/speed selection" has no effect because the COP timer clock source is CGMXCLK.
- **AsynchroSerial**:
  - Timing setting 'values from list' enables to select various values denoted by changes of the prescaler most tightly coupled with UART.
  - If a software handshake is used for extremely high baud-rates it may happen that no overruns appear and transmitted characters get lost
- **AsynchroMaster**: Same as AsynchroSerial
- **AsynchroSlave**: Same as AsynchroMaster.
- **SynchroMaster**: Because of the disability of an SPI device (configured as Master) caused by a mode fault, the mode fault automatically disables the component (inside an interrupt service) if interrupt service is enabled. If the interrupt service disabled and a mode fault occurs, the component will be disabled at the beginning of RecvChar method.
- **SynchroSlave**:
  - *On HC08 family MCUs:* A mode fault doesn't disable an SPI device (configured as Slave), therefore it doesn't disable the component.
    If a mode fault error occurs, software can abort the SPI transmission by disabling and enabling of the device ('Enable' and 'Disable' methods).
  - When Clock edge property = "falling edge", Shift clock idle polarity property = "Low" or Clock edge property = "rising edge" and Shift clock idle polarity property = "High", the SS pin of the slave SPI module must be set to logic 1 between bytes. The falling edge of SS indicates the beginning of the transmission. This causes the SPI to leave its idle state and begin driving the MISO pin with the MSB of its data. Once the transmission begins, no new data is allowed into the shift register from the data register. Therefore, the slave data register must be loaded with the desired transmit data before the falling edge of SS.
- **BitIO, BitsIO, ByteIO, Byte2IO, Byte3IO, Byte4IO**:
  The *GetVal* and *GetDir* methods are always implemented as macros. *Optimization for* property (BitIO, BitsIO) doesn't influence the generated code.
- **WordIO, LongIO**:
  These components could not be implemented on Freescale HC08 - this CPU has no instructions for 16-bit

and 32-bit access into the I/O space.

- **ADC:** Clock input of A/D clock generator cannot be changed in runtime.
  A conversion time in the 'Conversion time' dialog box is calculated for the worse case, which is usually 17 cycles per one conversion.

- **ExtInt**:
  If a pin other than IRQ (IRQ1) is set in this component, setting of the 'Pull resistor' property affects only disable state of the device (component). If the device (component) is enabled, the pull-up resistor is always connected to the pin.
- **KBI**:
  - *Limitation for HC08:* Setting of the 'Pull resistor' property affects only the disabled state of the device (component). If device (component) is enabled, the pull-up resistors are always connected to the used pins.
  - Only one KBI component can be used to handle one peripheral in PE project.
- **IntEEPROM**:
  A component expects that all security options of EEPROM are disabled. If some security option is enabled methods performing write operation (such as SetByte) can return an error.
- For details on sharing and usage of the **high-level timer components**, please see *3.4.3.1 HC(S)08/ColdFire V1 Timers Usage and Sharing*.

3.4.3.1. HC(S)08/ColdFire V1 Timers Usage and Sharing

The HC(S)08 and ColdFire V1 microcontrollers provide two main groups of timer devices.

Single-channel Timer Peripherals

These devices are simple counters that do not contain multiple individually configurable channels and usually do not allow to control any pins. These devices cannot be shared (i.e. used by multiple components).

The following devices are members of this group:

- **HC08:** PIT (TIM on some derivatives), TBM, PWU, RTC
- **HCS08, RS08, ColdFire V1:** RTI, CMT, MTIM, RTC, TOD

These devices are usually listed in Processor Expert under their original names without any extensions. These devices can be used by the following high-level components: **TimerInt, RTIshared, TimerOut and FreeCntr8/16/32.** The MTIM peripheral can additionally be used in event counter components (EventCntr8/16/32). All peripherals from this group are also supported by the Peripheral Initialization Components (*3.2.1.1 Component Categories*).

Multi-channel Timer Peripherals

These timer peripherals provide multiple channels and allow several modes of operation.

The following devices are members of this group:

- **HC08:** TIM (Timer Interface Modules)
- **HCS08, RS08, ColdFire V1:** TPM and FTM (Timer/PWM modules)

Processor Expert shows each of these timer peripherals as multiple devices that can be used by the components. The name of such device (shown in the peripheral selection list) consists of the peripheral and a suffix specifying the part of the peripheral or it's specific function. These named devices represent the whole peripheral or parts of the peripheral set to work in a specific mode. Using only a part of the timer allows to share the timer by multiple components.

The following devices are usually defined for the complex timer peripherals:
(the examples are for the MC68HC908AZ60 CPU)

- **TIMx (e.g. TIMA)** - The whole timer including counter, all channels and control registers. Name of the device should be same as name listed in datasheet. (Sometimes the 'x' is omitted if there is only one such timer on the chip). This device blocks all other devices defined for this timer.
- **TIMxy (e.g. TIMA0)** - Channel 'y' of the timer TIMx.
- **TIMxfree (e.g. TIMAfree)** - This device represents the overflow flag and the interrupt capabilities of the counter. The range is of the counter is not limited and it is determined by the size of the counter register so the timing is controlled only by the prescaler selection.
- **TIMx_PPG (e.g. TIMA_PPG)** - The whole timer in a programmable pulse generation mode. If the timer is used in this mode, it is not possible to use any of the TIMx, TIMxy and TIMxfree devices.
- **TIMxPP (e.g. TIMAPP)** - modulo register of the timer in a programmable pulse generation mode, that controls period of the generated signal.
- **TIMxyPPG (e.g. TIMA0PPG)** - channel 'y' of the timer 'TIMx' in the programmable pulse generation mode.

Note: Even though the multiple devices defined for a timer are configured independently, they can be mutually dependent. For example, they share one common prescaler. Processor Expert instantly checks components configuration and only valid combinations are allowed. See 3.3.4 Timing Settings for details.

Timing Model Restrictions for High level components

- **TOD** - Interrupt each 1/4 second is not available.
- **TPM** - It is not possible to select interrupt after 1 tick of the counter, because of hardware restrictions. At least 2 ticks must be used.
- **MTIM1 as a shared prescaler** - On some derivatives MTIM1 can be used as a clock-source for other timers. This feature allows the user to select large range of timing; even the timing model does not support all combinations of the MTIM1 prescaler and the modulo register.

Using Complex Timers in High Level Components

This chapter explains the options of usage of the complex timers in the high-level components allowing the user to benefit from the advanced features of these components. All peripherals from this group are also supported by the Peripheral Initialization Components (for details please see the chapter *3.2.1.1 Component Categories*).

The following table shows a list of the timer components and PE devices that can be used in the components as

rows. The columns show the state of all devices defined for the timer for conditions determined by rows.

Component	Selected device(s)	PE devices defined for the timer					
		TIMx	TIMxy	TIMxfree	TIMx_PPG	TIMxPP	TIMxyPPG
PWM	TIMxy	Blocked	Used 1 channel (2 in buffered mode) Others free	Blocked	Blocked	Blocked	Blocked
PPG	TIMxPP TIMxyPPG	Blocked	All channels blocked	Blocked	Used	Used	Used
TimerOut	TIMxy	Blocked	Used 1 channel (2 in buffered mode) Others free	Free	Blocked	Blocked	Blocked
TimerInt RTIShared TimeDate FreeCntr8 FreeCntr6 FreeCntr32	TIMxy	Blocked	Used 1 channel Others free	Free	Blocked	Blocked	Blocked
	TIMxfree	Blocked	All channels free	Used	Blocked	Blocked	Blocked
EventCntr8 EventCntr16 EventCntr32	TIMx	Used	All channels blocked	Blocked	Blocked	Blocked	Blocked
Capture	TIMxy	Blocked	Used 1 channel Others free	Free	Blocked	Blocked	Blocked

Table legend:

- Blocked - Device might not be directly used by the component but it cannot be used (shared) by other components because it would disrupt the component's function.
- Used - Device is required and used by the component.
- Free - Device is not used nor blocked by the component so it can be used by another component.

How to Use the Table

The table allows to easily find out which components (in which setup) can share the timer peripheral. The following rule determines the condition necessary for sharing: **When you take the rows of table corresponding to the components and their configurations you want to use, every column containing "Used" value must contain "Free" in all other rows (it cannot be used or blocked). In case of individual channels, there has to be enough channels for all components.** Please note that if a component allocates some channels, it is possible to share the timer among several components of the same type (e.g. TimerInt using the TIMxy device).

PWM Sharing Limitation

There are some limitations for the PWM component, if it shares the timer peripheral with other devices. The PWM in this case uses the whole range of the counter (i.e. the modulo register is not used) so the period values are limited to the value(s) determined by the prescaler value.

Example

The 68HC908AZ60 contains two timer modules TIMA and TIMB. Each one of these modules is based on a 16-bit counter that can operate as a free-running counter or a modulo-up counter. TIMB module has 2 channels and 2 related input/output pins. Can we use the TIMB peripheral for PWM output and input capture components at once?

Timer Module B (TIMB) is supported in PE by the following devices: TIMB, TIMB0, TIMB1, TIMBfree, TIMB_PPG, TIMBPP, TIMB0PPG, TIMB1PPG.
It follows from the table in this chapter that:

- For the PWM component (in non-buffered mode) you use only one channel (e.g.**TIMB0**). According to the columns, the component will use one channel and TIMBfree device, other channels will stay free, all other devices will be blocked.
- The Capture component, according to the columns, uses only one channel. Such channel is available: **TIMB1.**
- Sharing of the TIMB peripheral by the PWM and Capture component is possible. There is no remaining free device on the timer peripheral.

Because the channels of this timer are sharing one prescaler, it is necessary to configure the same prescaler value for both the PWM component and the Capture component.

3.4.3.2. Debugging on HC08 Using MON8

Every member of the HC08 microcontroller family is equipped with a basic support for in-system programming and debugging (MON8, for details see datasheet of a HC08 processor). The microcontroller can work in two modes - normal and monitor.

In the monitor mode the microcontroller can accept couple of commands over the single wire interface. The commands allow to read/write the memory and run a code. In combination with Break module a simple debugging system can be built (e.g. ICS boards, P&E Multilink, or various custom designs).

There are few issues that results from the characteristics of the MON8 system:

- To achieve a standard communication speed (19200, 9600, 4800 bauds) a specific oscillator frequency must be used (usually 9.83 or 4.915MHz). Suitable source of processor clock is usually part of the debugging system. The user must set the same clock frequency in the CPU component of his project to ensure that the timing of components will be correct. Care must be taken when using PLL and speed modes. Change of the operating frequency of the target processor can result in loss of communication with the target system.
- Some processor models allows to by-pass internal divider-by-2, which effectively doubles the bus clock of the processor. The bypass is selected by logic state of selected input pin (e.g. PTC3) during processor reset. The user must set appropriate property in the CPU component to reflect actual state of the pin.
- One I/O pin (e.g. PTA0) is used for communication with the host computer, therefore it can't be used as a general I/O pin.
- In some configuration of the debugging system, the IRQ pin can be also used to control the target board, therefore it can't be used in user application.

Capturing unused interrupts

The debugging system based on MON8 allows only one breakpoint placed in the flash memory. However, executing an SWI instruction while running is functionally equivalent to hitting a breakpoint, except that execution stops at the instruction following the SWI. The user can use this feature to actively capture unused interrupts. There are two options for capturing such interrupts:

- If the property named '*Unhandled interrupts*' located in *Build Options* tab is set to *Own handler for every*, there is an interrupt routine generated for each unhandled interrupt generated into the CPU.c module. The SWI instruction can be placed in the generated routine of the interrupt that need to be caught.
- The user can also use the InterruptVector component. In the properties of the component, select which interrupt will be monitored and set the name of the ISR function, for example 'Trap'. One function can be used to capture more interrupts if property *Allow duplicate ISR names* is set to *yes*. The Trap function will contain only the SWI instruction:

```
__interrupt void Trap(void)
  {
    asm(SWI);
  }
```

3.4.4. Version Specific Information for RS08

The ROM and RAM ranges depend on the target CPU. The RESERVED_RAM size for pseudo registers storage is by default 5 bytes.

Component implementation details:

- **Interrupts**: Some of the RS08 derivatives do not support interrupts so the components on these CPUs are limited and some are not available. The following components are not available on the RS08 derivatives without interrupt support because they depend on interrupt(s): **ExtInt,TimerInt,FreeCntr8,FreeCntr16,FreeCntr32,RTIshared, InterruptVector,TimeDate**.
  Derivatives of the RS08 family with CPU core version 2 support a single global interrupt vector. The interrupt doesn't support a vector table lookup mechanism as used on the HC(S)08 devices. It is the responsibility of a routine servicing the global interrupt to poll the system interrupt pending registers (SIPx) to determine if an interrupt is pending. To support the single global interrupt vector Processor Expert defines a set of emulated interrupt vectors for each HW module, which duplicates interrupt vectors of the HCS08 family. When an emulated interrupt vector is used by a component a call to the appropriate interrupt service routine is added to the global interrupt service routine. The global interrupt vector routine performs check of the SIPx registers to determine if an interrupt is pending. The order in which the SIPx registers are polled is affected by priority of the emulated interrupts. For priority settings details please see the chapter *3.3.1.1 Processor Expert Priority System*.
- **CPU**:
  - *Speed Mode* selection (CPU methods *SetHighSpeed*, *SetLowSpeed*, *SetSlowSpeed*): if CPU clock-dependent components are used then signals generated from such internal peripherals may be corrupted at the moment of the speed mode selection (if function of clocked devices is enabled). Handling of such a situation may be done using events **BeforeNewSpeed** and **AfterNewSpeed**.
- **PPG**: The PPG components always allocate whole timer. Although it is possible to share the selected timer between 2 PPG components, it would be impossible to set the PPG period for these two components separately. More information about this component can be found in chapter Timers.

- **PWM**: In contrast to the PPG components, it is possible for PWM components to share the selected timer, since they do not have the *SetPeriod* method. More information about this component can be found in chapter Timers
- **WatchDog** : When the Watchdog component is added to the project, it is automatically enabled. The enabling code is placed in the CPU initialization code.
  Note: Watchdog is enabled by a write to the configuration register. This register can be written only once after CPU reset. Since the register also contains other bits, which are written during the CPU initialization, the watchdog must be enabled when CPU is initialized. The property "CPU clock/speed selection" has no effect because the COP timer clock source is CGMXCLK.
- **AsynchroSerial**: Timing setting 'values from list' enables to select various values denoted by changes of the prescaler most tightly coupled with UART.
- **SynchroMaster**: If a mode fault occurs, the component is disabled at the beginning of the RecvChar method.
- **SynchroSlave**: When Clock edge property = "falling edge", Shift clock idle polarity property = "Low" or Clock edge property = "rising edge" and Shift clock idle polarity property = "High", the SS pin of the slave SPI module must be set to logic 1 between bytes. The falling edge of SS indicates the beginning of the transmission. This causes the SPI to leave its idle state and begin driving the MISO pin with the MSB of its data. Once the transmission begins, no new data is allowed into the shift register from the data register. Therefore, the slave data register must be loaded with the desired transmit data before the falling edge of SS.
- **BitIO, BitsIO, ByteIO, Byte2IO, Byte3IO, Byte4IO**:
  The *GetVal* and *GetDir* methods are always implemented as macros. *Optimization for* property (BitIO, BitsIO) doesn't influence the generated code.
- **ADC:** Clock input of A/D clock generator cannot be changed in runtime.
  A conversion time in the 'Conversion time' dialog box is calculated for the worst case.
- **KBI**: Only one KBI component can be used to handle one peripheral in PE project.
- For details on sharing and usage of the **high-level timer components** please see the chapter *3.4.4.1 RS08 Timers Usage and Sharing*.

3.4.4.1. RS08 Timers Usage and Sharing

RS08 microcontrollers provide two main groups of timer devices.

Simple Timer Peripherals

These devices are simple counters that do not contain multiple individually configurable channels and usually do not allow to control any pins. These devices cannot be shared (i.e. used by multiple components).

The following devices are members of this group on RS08: **RTI, MTIM**

These devices are usually listed in Processor Expert under their original names without any extensions. These devices can be used by the TimerOut component. The MTIM peripheral can additionally be used in event counter components (EventCntr8,16,32). All peripherals from this group are also supported by the Peripheral Initialization Components (for details please see the chapter *3.2.1.1 Component Categories*).

Complex Timer Peripherals

These timer peripherals provide multiple channels and allow several modes of operation.

The RS08 contains only one device of such kind: **TPM** (Timer/PWM modules)

Processor Expert shows each of these timer peripherals as multiple devices that can be used by the components. The name of such device (shown in the peripheral selection list) consists of the peripheral and a suffix specifying the part of the peripheral or it's specific function. These named devices represent the whole peripheral or parts of the peripheral set to work in a specific mode. Using only a part of the timer allows to share the timer by multiple components.

The following devices are usually defined for the complex timer peripherals:
(the examples are for MC9RS08SA12 CPU)

- **TPM** (e.g. TPM) - Whole timer including all channels and control registers. (Sometimes the 'x' is omitted if there is only one such timer on the chip). This device blocks all other devices defined for this timer.
- **TPMxy** (e.g. TPM1) - Channel 'y' of the timer 'x'. (Sometimes the 'x' is omitted if there is only one timer on the chip)
- **TPMx_PPG** (e.g. TPM_PPG) - Whole timer in a programmable pulse generation mode. (Sometimes the 'x' is omitted if there is only one timer on the chip)
- **TPMxPP** (e.g. TPMPP) - Modulo register of the timer in a programmable pulse generation mode. (Sometimes the 'x' is omitted if there is only one timer on the chip)
- **TPMxyPPG** (e.g. TPMPPG) - Channel 'y' of the timer 'x' in the programmable pulse generation mode. (Sometimes the 'x' is omitted if there is only one timer on the chip)
- **TPMxfree** (e.g. TPMfree) - This device represents the overflow flag and interrupt capabilities of the counter. The range is of the counter is not limited and it is determined by the size of the counter register so the timing is controlled only by the prescaler selection. (Sometimes the 'x' is omitted if there is only one timer on the chip)

Note: Even though the multiple devices defined for a timer are configured independently, they can be mutually dependent. For example, they share one common prescaler. Processor Expert instantly checks components configuration and only valid combinations are allowed. See 3.3.4 Timing Settings for details.

Using Complex Timers in High Level Components

This chapter explains the options of usage of the complex timers in the high-level components allowing the user to benefit from the advanced features of these components. All peripherals from this group are also supported by the Peripheral Initialization Components (for details please see the chapter *3.2.1.1 Component Categories*).

The following table shows a list of the timer components and PE devices that can be used in the components as rows. The columns show the state of all devices defined for the timer for conditions determined by rows.

Component	Selected device(s)	PE devices defined for the timer					
		TIMx	TIMxy	TIMxfree	TIMx_PPG	TIMxPP	TIMxyPPG
PWM	TIMxy	Blocked	Used 1 channel (2 in buffered mode) Others free	Blocked	Blocked	Blocked	Blocked
PPG	TIMxPP TIMxyPPG	Blocked	All channels blocked	Blocked	Used	Used	Used
TimerOut	TIMxy	Blocked	Used 1 channel (2 in buffered mode) Others free	Free	Blocked	Blocked	Blocked
EventCntr8 EventCntr16 EventCntr32	TIMx	Used	All channels blocked	Blocked	Blocked	Blocked	Blocked
Capture	TIMxy	Blocked	Used 1 channel Others free	Free	Blocked	Blocked	Blocked

Table legend:

- Blocked - Device might not be directly used by the component but it cannot be used (shared) by other components because it would disrupt the components' function.
- Used - Device is required and used by the component.
- Free - Device is not used nor blocked by the component so it can be used by another component.

How to Use the Table

The table allows to easily find out which components (in which setup) can share the timer peripheral. The following rule determines the condition necessary for sharing: **When you take the rows of table corresponding to the components and their configurations you want to use, every column containing "Used" value must contain "Free" in all other rows (it cannot be used or blocked). In case of the individual channels there has to be enough channels for all components.** Please note that if a component allocates some channels, it is possible to share the timer among several components of the same type (e.g. TimerInt using the TIMxy device).

PWM Sharing Limitation

There are some limitations for the PWM component, if it shares the timer peripheral with other devices. The PWM in this case uses the whole range of the counter (i.e. the modulo register is not used) so the period values are limited to the value(s) determined by the prescaler value.

3.4.5. Version Specific Information for Kinetis

Only the Peripheral Initialization and Logical Device Drivers (LDD) components are available for the Kinetis derivatives. For details please see the section *3.2.1.2 Logical Device Drivers* and *3.2.1.1 Component Categories*.

Kinetis CPU components support **Clock configurations** that are similar to "Speed Modes" (see *3.2.2.2 Speed Modes Support*) but provide more options on configuring low power and slow clock modes of the CPU. Please find details on individual settings in the CPU component's on-line help.

3.5. Code Generation and Usage

This chapter informs the user about the principles and results of the Processor Expert code generation process and the correct ways and possibilities of using this code in the user application.

Please refer to the following subchapters for more information:

- Code Generation
- Predefined Types, Macros and Constants
- Typical Usage of Component in User Code
- User Changes in Generated Code

3.5.1. Code Generation

ProcessorExpert.pe pop-up menu > Generate Processor Expert Code

Generate Code command initiates the code generation process. During this process source code modules containing functionality of the components contained in the project are generated. The project must be set-up correctly for successful code generation. If the generation is error-free all generated source code files are saved to the destination directory.

Files Produced by Processor Expert

The existence of the files can be conditional to project or Processor Expert environment settings and their usage by the components.

- **Component module**
  This module with its header file is generated for every component in the project with exception of some components that generate only an initialization code or special source code modules. Name of this file is the same as the name of the component.
  Header file (.h) contains definitions of all public symbols, which are implemented in the component module and can be used in the user modules.
  The module contains implementation of all enabled methods and may also contain some subroutines for internal usage only.

- **CPU module**
  The CPU module is generated according to the currently active target CPU component. The CPU module additionally contains:
  - MCU initialization code

- interrupt processing

- **Main module**
  The main module is generated only if it does not already exist (if it exists it is not changed). Name of this module is the same as the name of the project.
  The main module contains the **main** function, which is called after initialization of the MCU (from the CPU module). By default this function is generated empty (without any reasonable code). It is designed so that the user can write code here.

- **Event module**
  The event module is generated only if it does not exist. If it exists, only new events are added into the module; user written code is not changed.
  The event module contains all events selected in the components. By default these event handler routines are generated empty (without any meaningful code). It is considered that user will write code here.
  Event module can also contain the generated ISRs for the components that require a direct interrupt handling (Peripheral Initialization Components). It is possible to configure the name of event module individually for each component in the ADVANCED view mode of the Component Inspector. However, please note that the event module is not generated by Processor Expert if there is no event enabled in the component, except the CPU component, for which the event module is always generated.

- **Method list file** with description of all components, methods and events generated from your project. The name of the file is *{projectname}.txt* or *{projectname}.doc*. This documentation can be found in the *Documentation* folder of the Project Panel.

- **Signal names**
  This is a simple text file *{projectname}_SIGNALS.txt* or *{projectname}_SIGNALS.doc* with a list of all used signal names. The signal name can be assigned to an allocated pin in the component properties (available in ADVANCED view mode). This documentation can be found in the Documentation folder of the Project Panel. See *3.3.6 Signal Names* for details.

- **Code generation log** that contains information on changes since last code generation. See *3.5.1.1 Tracking Changes in Generated Code* for details.

- **XML documentation** containing the project information and settings of all components in XML format. The generated file *{projectname}_Settings.xml* can be found in the Documentation folder of the Project Panel. It is updated after each successful code generation.

- **Shared modules** with shared code (the code which is called from several components). Complete list of generated shared modules depends on selected CPU, language, compiler and on the current configuration of your project. Typical shared modules are:
  - **IO_Map.h**
    Control registers and bit structures names and types definitions in C language.
  - **IO_Map.c**
    Control registers variable declarations in C language. This file is generated only for the HC(S)08/HC(S)12 versions.
  - **Vectors.c**
    A source code of the interrupt vector table content.

- **PE_Const.h**
  Definition of the constants, such as speed modes, reset reasons. This file is included in every driver of the component.
- **PE_Types.h**
  Definition of the C types, such as bool, byte, word. This file is included in every driver of the component.
- **PE_Error.h**
  Common error codes. This file contains definition of return error codes of component's methods. See the generated module for detailed description of the error codes. This file is included in every driver of the component.
- **PE_Timer**
  This file contains shared procedures for runtime support of calculations of timing constants.
- **{startupfile}.c**
  This external module, visible in the External Modules folder of the Project Panel, contains a platform specific startup code and is linked to the application. The name of the file is different for the Processor Expert versions. For datils on the use of the startupfile during the reset see chapter *3.4.1 Reset Scenario with PE for HC(S)08 and RS08*

See also chapter *3.5.2 Predefined Types, Macros and Constants*.

3.5.1.1. Tracking Changes in Generated Code

Processor Expert allows to track changes in generated modules. It's just necessary to enable the option **Create code generation log** in the Processor Expert Project options. See *2.1.1 Processor Expert Options* for details.. If this option is enabled, a file **ProcessorExpert_CodeGeneration.txt** is generated into Documentation folder.

The file contains a list of changes with details on purpose of each change. Please see the example below:

```
############################################################
Code generation 2010/10/22, 15:57; CodeGen: 1 by user:

by Processor Expert 5.00 for Freescale Microcontrollers; PE core 04.46
Configuration: Debug_S08GW64CLH
Target CPU: MC9S08GW64_64; CPUDB ver 3.00.000
# The following code generation options were changed:

 > option Create code generation log: value changed from false to true
############################################################
Code generation 2010/10/22, 16:01; CodeGen: 2 by user: hradsky

by Processor Expert 5.00 Beta for Freescale Microcontrollers; PE core 04
Configuration: Debug_S08GW64CLH
Target CPU: MC9S08GW64_64; CPUDB ver 3.00.000

# Component Cpu:MC9S08GW64_64, the following files modified due to inter
 - Generated_Code\Vectors.c - changed
 - Generated_Code\Cpu.h - changed
```

```
 - Generated_Code\Cpu.c - changed

# New component PWM1:PWM (ver: 02.231, driver ver. 01.28) added to the p
 - Generated_Code\PWM1.h - added
 - Generated_Code\PWM1.c - added
# Documentation
 - Documentation\ProcessorExpert.txt - regenerated
 - Documentation\ProcessorExpert_Settings.xml - regenerated

# Other files have been modified due to internal interdependency:
 - Generated_Code\PE_Timer.h - added
 - Generated_Code\PE_Timer.c - added
# User modules
 - Sources\ProcessorExpert.c - changed
  > updated list of included header files
 - Sources\Events.h - changed
  > updated list of included header files
Totally 11 file(s) changed during code generation.
```

To view changes within the individual files, the user can use a file pop-up menu command **Compare with** > **Local history...** available in Project panel. It allows to compare files with the version before the code generation.

3.5.2. Predefined Types, Macros and Constants

Processor Expert generates definitions of all hardware register structures to the file **IO_Map.h.** The Processor Expert type definitions are generated to the file **PE_Types.h** which also containins definitions of macros used for a peripheral register access. See *3.8.2 Direct Access to Peripheral Registers* for details.

Types

Type	Description	Supported for
byte	8-bit unsigned integer (unsigned char)	all
bool	Boolean value (unsigned char) (TRUE = any non-zero value / FALSE = 0)	all
word	16-bit unsigned integer (unsigned int)	all
dword	32-bit unsigned integer (unsigned long)	all
dlong	array of two 32-bit unsigned integers (unsigned long)	all
TPE_ErrCode	Error code (uint8_t)	all except MPC55xx

Structure for images

```
typedef struct {          /* Image */
  word width;             /* Image width in pixels */
  word height;            /* Image height in pixels */
  byte *pixmap;           /* Image pixel bitmap */
```

```
  word size;              /* Image size in bytes */
  char *name;             /* Image name */
} TIMAGE;
typedef TIMAGE* PIMAGE ; /* Pointer to image */
```

Structure for 16-bit register:

```
/* 16-bit register (big endian format) */
  typedef union {
     word w;
     struct {
       byte high,low;
     } b;
  } TWREG;
```

Macros

```
  __DI()             - Disable global interrupts
  __EI()             - Enable global interrupts


  EnterCritical()    - It saves CCR register and disable
                       global interrupts
  ExitCritical()     - It restores CCR register saved
                       in EnterCritical()
```

For the list of macros available for Peripheral registers access, please see the chapter *3.8.2 Direct Access to Peripheral Registers*

Constants

Methods Error Codes

The error codes are defined in the *PE_Error* module. Error code value is 8-bit unsigned byte. Range 0 - 127 is reserved for PE, and 128 - 255 for user.

ERR_OK	0	OK
ERR_SPEED	1	This device does not work in the active speed mode
ERR_RANGE	2	Parameter out of range
ERR_VALUE	3	Parameter of incorrect value
ERR_OVERFLOW	4	Timer overflow
ERR_MATH	5	Overflow during evaluation
ERR_ENABLED	6	Device is enabled
ERR_DISABLED	7	Device is disabled
ERR_BUSY	8	Device is busy
ERR_NOTAVAIL	9	Requested value not available
ERR_RXEMPTY	10	No data in receiver
ERR_TXFULL	11	Transmitter is full

ERR_BUSOFF	12	Bus not available
ERR_OVERRUN	13	Overrun is present
ERR_FRAMING	14	Framing error is detected
ERR_PARITY	15	Parity error is detected
ERR_NOISE	16	Noise error is detected
ERR_IDLE	17	Idle error is detected
ERR_FAULT	18	Fault error is detected
ERR_BREAK	19	Break char is received during communication
ERR_CRC	20	CRC error is detected
ERR_ARBITR	21	A node loses arbitration. This error occurs if two nodes start transmission at the same time
ERR_PROTECT	22	Protection error is detected.
ERR_UNDERFLOW	23	Underflow error is detected.
ERR_UNDERRUN	24	Underrun error is detected.
ERR_COMMON	25	General unspecified error of a device. The user can get a specific error code using the method GetError.
ERR_LINSYNC	26	LIN synchronization error is detected
ERR_FAILED	27	Requested functionality or process failed.
ERR_QFULL	28	Queue is full.

3.5.3. Typical Usage of Component in User Code

This chapter describes usage of methods and events that are defined in most hardware oriented components. Usage of other component specific methods is described in the component documentation, in the section "Typical Usage" *(if available)*.

Peripheral Initialization Components

Peripheral Initialization Components are the components at the lowest level of peripheral abstraction. These components contain only one method Init providing the initialization of the used peripheral. See *3.5.3.1 Typical Usage of Peripheral Initialization Components* for details.

Peripheral Initialization Components

Plese see the chapter For typical usage and hints on Logical Device Drivers (LDD components) please see the chapter *3.5.3.2 Typical LDD Components Usage*

High level components

Methods Enable, Disable

Most of the hardware components support the methods Enable and Disable. These methods enable or disable peripheral functionality, which causes disabling of functionality of the component as well.
Hint: Disabling of the peripheral functionality may save CPU resources.

Overview of the method behavior according to the component type:

- Timer components: timer counter is stopped if it is not shared with another component. If the timer is shared, the interrupt may be disabled (if it is not also shared).
- Communication components, such as serial or CAN communication: peripheral is disabled.
- Conversion components, such as A/D and D/A: converter is disabled. The conversion is restarted by Enable.

If the component is disabled, some methods may not be used. Please refer to components documentation for details.

MAIN.C

```
void main(void)
{
  ...
  B1_Enable();   /* enable the component functionality */
              /* handle the component data or settings */
  B1_Disable(); /* disable the component functionality */
  ...
}
```

Methods EnableEvent, DisableEvent

These methods enable or disable invocation of all component events. These methods are usually supported only if the component services any interrupt vector.

The method DisableEvent may cause disabling of the interrupt, if it is not required by the component functionality or shared with another component. The method usually does not disable either peripheral or the component functionality.

MAIN.C

```
void main(void)
{
  ...
  B1_EnableEvent();  /* enable the component events */
                     /* component events may be invoked */
  B1_DisableEvent(); /* disable the component events */
                     /* component events are disabled */
  ...
}
```

Events BeforeNewSpeed, AfterNewSpeed

Timed components that depend on the MCU clock such as timers, communication and conversion components, may support speed modes defined in the CPU component (in EXPERT view level). The event BeforeNewSpeed is invoked before the speed mode changes and AfterNewSpeed is invoked after the speed mode changes. Speed mode may be changed using the CPU component methods SetHigh, SetLow, or SetSlow.

EVENT.C

```
int changing_speed_mode = 0;

void B1_BeforeNewSpeed(void)
{
  ++changing_speed_mode;
}

void B1_AfterNewSpeed(void)
{
  --changing_speed_mode;
}
```

Note: If the speed mode is not supported by the component, the component functionality is disabled, as if the method Disable is used. If the supported speed mode is selected again, the component status is restored.

TRUE and FALSE Values of bool Type

Processor Expert defines the TRUE symbol as 1, however true and false logical values in C language are defined according to ANSI-C:

- False is defined as 0 (zero)
- True is any non-zero value

It follows from this definition, that the bool value cannot be tested using the expressions, such as `if (value == TRUE) ...`
Processor Expert methods returning bool value often benefit from this definition and they return any non-zero value as TRUE value instead of 1. The correct C expression for such test is: **`if (value) ...`**.

In our documentation, the "true" or "false" are considered as logical states, not any particular numeric values. The capitalized "TRUE" and "FALSE" are constants defined as FALSE=0 and TRUE=1.

3.5.3.1. Typical Usage of Peripheral Initialization Components

Init method

Init method is defined in all Peripheral Initialization Components. Init method contains a complete initialization of the peripheral according to the component's settings.

In the following examples, let's assume a component named "Init1" has been added to the project.

The Init method of the Peripheral Initialization component can be used in two ways.

- The Init method is called by Processor Expert
- The Init method is called by the user in his/her module

Automatic calling of Init
The user can let Processor Expert call the Init method automatically by selecting "yes" for the **Call Init method** in the Initialization group of the Component's properties.

When this option is set, Processor Expert places the call of the Init method into the *PE_low_level_init* function of the CPU.c module.

Manual calling of Init
Add the call of the Init method into the user's code, for example in main module.

Enter the following line into the main module file:

```
Init1_Init();
```

Put the Init method right below the PE_low_level_init call.

```
void main(void)
{
  /*** Processor Expert internal initialization. ***/
  PE_low_level_init();
  /*** End of Processor Expert internal initialization. ***/
  Init1_Init();
  for(;;) {}
}
```

Interrupt Handling

Some Peripheral Initialization components allow the initialization of an interrupt service routine. Interrupt(s) can be enabled in the initialization code using appropriate properties that can be usually found within the group *Interrupts*.
After enabling, the specification of an Interrupt Service Routine (ISR) name using the *ISR name* property is required. This name is generated to Interrupt Vector table during the code generation process. Please note that if the ISR name is filled, it is generated into the Interrupt Vector Table even if the interrupt property is disabled.

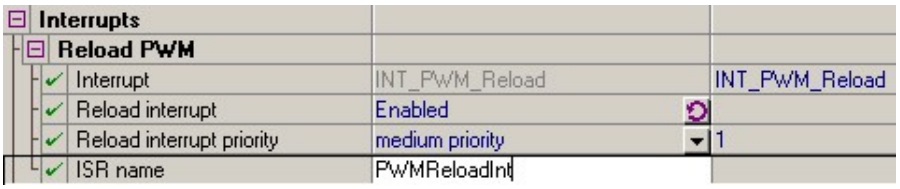


Figure 3.16 - Example Of The Interrupt Setup

Enabling/disabling peripheral interrupts during runtime has to be done by user's code, for example by utilizing PESL or direct register access macros, because the Peripheral Initialization Components do not offer any methods for interrupt handling.

The ISR with the specified name has to be declared according to the compiler conventions and fully implemented by the user.

3.5.3.2. Typical LDD Components Usage

Init method

The **Init()** method is defined in all Logical Device Drivers. The **Init()** method contains a complete initialization of the peripheral according to the component's settings. See *3.2.1.2 Logical Device Drivers* for details.

The following example shows how to use Init method in user code, main module in this case. Let's assume a component named "**AS1**" has been added to the project.

The user needs to add the call of the Init method into the user code, for example in main module.

```
void main(void)
{
  LDD_TDeviceStructure MyDevice;

  /*** Processor Expert internal initialization. ***/
  PE_low_level_init();
  /*** End of Processor Expert internal initialization. ***/

  MyDevice = AS1_Init(NULL); /* Initialize driver and peripheral */

  . . .

  AS1_Deinit(MyDevice);      /* Deinitialize driver and peripheral */

  for(;;) {}
}
```

Deinit method

Deinit() method disables a peripheral and frees the allocated memory if supported by the RTOS adapter. Deinit() method is usually used in RTOS applications, not in bare-metal applications.

Interrupt Handling

Most of LDD components are designed to be used in the interrupt mode. It means that the interrupt service routine (ISR) is called by the interrupt controller when an asynchronous interrupt occurs. Interrupt service routine is defined in LDD driver and a user is notified through component’s events. Events can be enabled or disable in the component inspector according to an application needs. When an event is enabled, the appropriate function is generated into Event.c, where a user can write own event handler code. Events are called from the ISR context, so a user should keep an event code as short as possible to minimize a system latency.

3.5.4. User Changes in Generated Code

It's necessary to say at the beginning of the chapter, that modification of the generated code may be done only at user's own risk. Generated code was thoroughly tested by the skilled developers and the functionality of the modified code cannot be guaranteed. We strongly don't recommend modification of the generated code to the beginners. See more information for generated modules in chapter Code Generation.

To support user changes in the component modules, Processor Expert supports the following features:

Code generation options for component modules

It's possible to select mode of the code generation for each component, the following options can be found in the components's pop-up menu in the **project panel**:

- **Always Write Generated Component Modules** (default) - generated component modules are always written to disk and any existing previous module is overwritten
- **Don't Write Generated Component Modules** - the code from component is not generated. Any initialization code of the component, which resides in the CPU component, interrupt vector table and shared modules are updated.

Freezing the Code generation

Sometimes, there is unwanted any change in the code generated by Processor Expert. It's for example in case of manual modification done by the user and the user doesn't want to loose the code by accidental re-generation of PE project. For such cases there is an option in Processor Expert Project Options that completely disables the code generation. See *2.1.1 Processor Expert Options* for details.

3.6. Embedded Component Optimizations

This chapter describes how the size and speed of the code could be optimized by choosing right component for the specific task. It also describes how to setup components to produce optimized code. The optimizations that are described are only for the High or Low level components, not for the Peripheral Initialization components.

Please refer to sub-chapters for more details:

- General Optimizations
- General Port I/O Optimizations
- Timer Components Optimizations
- Code Size Optimization of Communication Components

3.6.1. General Optimizations

This chapter describes how to setup Processor Expert and components to generate optimized code. The following optimization are only for the High or Low-level components, and not for the Peripheral Initialization components.

Disabling Unused Methods

Note: These optimization are not usable for the Peripheral Initialization Components.
When Processor Expert generates the code certain methods and events are enabled by default setting, even when the methods or events are not needed in the application, and thus while they are unused, the code may still take memory. Basically, the unused methods code is dead stripped by the linker but when the dependency among methods is complex some code should not be dead stripped. When useless methods or events are enabled the generated code can contain spare source code because of these unused methods or events. Moreover some methods can be replaced by more efficient methods that are for special purposes and therefore these methods are not enabled by default.

Disabling Unused Components

Disable unused and test purpose components or remove them from the project. Disabling of these components is sufficient because the useless code is removed but the component setting remains in the project. If these components are required for later testing then add a new configuration to the project and disable these useless component only in the new configuration. The previous configuration will be used when the application is tested again. Moreover if it is required to use the same component with different setting in several configurations, its possible to add one component for each configuration with same name and different setting.

Speed modes

Note: These optimizations are not usable for the Peripheral Initialization Components.
Timed components which depend on the CPU clock (such as timer, communication and conversion components), may support speed modes defined in the CPU component (in EXPERT view level). The Processor Expert allows the user to set closest values for the component timing in all speed modes (if possible) . If the requested timing is not supported by the component, for example if the CPU clock is too low for the correct function of the component, the component can be disabled for the appropriate speed mode. The mode can be switched in the runtime by a CPU method. The component timing is then automatically configured for the appropriate speed mode or the component is disabled (according to the setting). Note, however, that use of speed modes adds extra code to the application. This code must be included to support different clock rates. See speed mode details here.

See chapter Embedded Components Optimizations for details on choosing and setting the components to achieve optimized code.

3.6.2. General Port I/O Optimizations

Note: These optimizations are not usable for the Peripheral Initialization Components.

ByteIO Component Versus BitsIO Component

ByteIO component instead of BitsIO component should be used when whole port is accessed. The BitsIO component is intended for accessing only part of the port (e.g. 4 bits of 8- bit port)

Using the BitsIO component results more complex code because this component provides more general code for the methods, which allows access to only some of the bits of the port. On the other side, the ByteIO component provides access only to the whole port and thus the resulted code is optimized for such type of access.

BitsIO component versus BitIO components

In case of using only a part of the port the multiple BitIO components could be used. A better solution is to use the BitsIO component replacing multiple calls of the BitIO component's methods. The application code consist only of one method call and is smaller and faster.

3.6.3. Timer Components Optimizations

Note: These optimizations are not usable for the Peripheral Initialization Components.

For better **code size performance,** it's recommended to not to use a bigger counter/reload/compare register for timer than is necessary. Otherwise the code size generated by a component may be increased (e.g. For 8-bit timer choose 8bit timer register).

In some cases, several timing periods are required when using timers (For example, the TimerInt component). The Processor Expert allows changing the timer period during run-time using several ways (note that this is an advanced option and the Component Inspector Items visibility must be set to at least 'ADVANCED').

These ways of changing the run-time period of timer requires various amount of code and thus the total application code size is influenced by the method chosen. **When the period must be changed during run-time**, use fixed values for period instead of an interval if possible to save code. There are two possibilities (See *2.4.3.1 Dialog Box for Timing Settings* for details.):

- **From list of values** - this allow to specify several (but fixed in run-time) number for given periods. This allows only exact values - modes, listed in the listbox. The resulted code for changing the period is less complex than using an interval.
- **From time interval** - this is an alternative to using 'list of values', which requires more code. Using an interval allows setting whatever value specified by the component during run-time. This code re-calculates the time period to the CPU ticks and this value is used when changing the timer period.

If the application requires only a few different timing periods, even if the functionality is the same for both cases, the correct usage of list of periods produces smaller code compared to code using an interval.

3.6.4. Code Size Optimization of Communication Components

Note: These optimizations are not usable for the Peripheral Initialization Components.
Communication components should be used with the smallest possible buffer. Thus the user should compute or check the maximum size of the buffer during execution of the application. For this purpose the method GetCharsInTxBuffer/GetCharsInTxBuffer (AsynchroSerial component), which gets current size of a used buffer, can be used after each time the SendBlock/RecvBlock method is called.

Use **interrupts** if you require faster application response. The interrupt routine is performed only at the event time, that is the code does not check if a character is sent or received. Thus the saved CPU time can be used by another process and application is faster.

Use **polling mode** instead of interrupts if you require less code because usually overhead of interrupts is bigger than overhead of methods in polling mode. But the polling mode is not suitable for all cases. For example when you use the SCI communication for sending only the data, and a character is sent once in a while, then it is better to use the polling mode instead of using interrupt because it saves the code size, that is when the interrupt is used an interrupt subroutine is needed and code size is increased.

Examples:

A module of an application sends once in a while one character to another device through the SCI channel. If the delay between two characters is sufficient to sent one character at a time then the polling mode of the SCI (the AsynchroSerial component) should be used in this case.

A module of an application communicates with another device, that is it sends several characters at one time and receives characters from the device. Thus the interrupt mode of the SCI (the AsynchroSerial component) should be used in this case because when a character is received the interrupt is invoked and the underlying process of the application need not check if a character is received. When a buffer for sending is used, the characters are saved into the buffer and AsynchroSerial's service routine of the interrupt sends these characters without additional code of the application.

Note: The polling mode of the component is switched on by disabling of the Interrupt service of the component (AsynchroSerial, AsynchroMaster, and AsynchroSlave).

3.7. Converting Project to Use Processor Expert

The C project that doesn't use Processor Expert can be can be converted to Processor Expert. This is useful when the user finds out that he/she would like to use additional features of Processor Expert.

Warning: Please note that in most cases this conversion involves necessary manual changes in the application code, because for example the register interrupt vectors table definitions created by the user often conflicts with Processor Expert definitions. Don't forget to backup the whole project before the conversion. Some files will have to be removed from the project. The conversion to Processor Expert is recommended to experienced users only.

Conversion Steps

1. Select the menu command **File > New > Other...**
2. Within the "Select a wizard" dialog box select **Processor Expert / Enable Processor Expert for Existing C Project** and click on the **Next** button.
3. Select the project that you would like to convert and the project type.
   - Processor Expert can generate initialization code and drivers for on-chip peripherals and also drivers for selected external peripherals or software algorithms. See *1.2 Features* for details.
   - Device Initialization is simpler tool that can generate initialization code for on-chip peripherals, interrupt vector table and template for interrupt vector service routines.
4. Select the MCU that the project is designed for.
5. Select the MCU variant(s) and Processor Expert configuarions that you would like to have available in the project.
6. Review the actions that Processor Expert is about to perform. You can uncheck the checkboxes for items you would like not to be done. Please ensure you have backed-up your project before confirming before you confirm by clicking on Finish.
7. Now it's necessary to move the application code from original **main.c** located in "Sources" folder into new **ProcessorExpert.c** generated by Processor Expert in previous step, consequently remove original main.c module from the project.

3.8. Low-level Access to Peripherals

In some cases, a non-standard use of the peripheral is required and it is more efficient to write a custom peripheral driver from scratch than to use the component. In addition, there are special features present only on a particular chip derivative (not supported by the component) that could make the user routines more effective; however, the portability of such code is reduced.

Peripheral Initialization

It is possible to use Processor Expert to generate only the initialization code (function) for a peripheral using the Peripheral initialization components. The user can choose a suitable Peripheral initialization component for the given peripheral using the Peripherals tab of the Components Library. See *2.3 Components Library View* for details. Initial values that will be set to the peripheral control registers can be viewed in the Peripheral Initialization window. See *2.7 Peripheral Initialization View* for details.

Peripheral Driver Implementation

The rest of the peripheral driver can be implemented by the user using one of the following approaches:

- Physical Device Drivers
- Direct Access to Peripheral Registers

Warning: Incorrect change in registers of the peripheral, which is controlled by any Component driver can cause the incorrect Component driver function.

3.8.1. Physical Device Drivers

Note: PDD layer is available only for Kinetis family MCUs.

Physical Device Drivers (PDD) is a software layer that provides set of methods for accessing MCU peripheral configuration registers.

PDD methods abstract from:

- What kind of registers are available
- How registers are organized
- How they are named

PDD header files are located in `{CodeWarrior}\Processor Expert\lib\{MCU}\pdd`.
Each file contains a definitions of PDD methods for one MCU peripheral. Basic PDD methods are implemented by macros and do not provide any additional functionality like register masking, shifting, etc.

3.8.2. Direct Access to Peripheral Registers

Note: Register access macros are not available for Kinetis family MCUs.

The direct control of the Peripheral's registers is a low-level way of creating peripheral driver which requires a good knowledge of the target platform and the code is typically not portable to different platform. However, in some cases is this method more effective or even necessary to use (in the case of special chip features not encapsulated within the Embedded component implementation). See *3.8 Low-level Access to Peripherals* for details.

Register Access Macros

Processor Expert defines a set of C macros providing an effective access to a specified register or its part. The definitions of all these macros are in the file **PE_Types.h**. The declaration of the registers which could be read/written by the macros is present in the file **IO_Map.h**.

Whole Register Access Macros

- **getReg{w}** (*RegName*) - Reads the register content
- **setReg{w}** (*RegName, RegValue*) - Sets the register content

Register Part Access Macros

- **testReg{w}Bits** (*RegName, GetMask*) - Tests the masked bits for non-zero value
- **clrReg{w}Bits** (*RegName, ClrMask*) - Sets a specified bits to 0.
- **setReg{w}Bits** (*RegName, SetMask*) - Sets a specified bits to 1.
- **invertReg{w}Bits** (*RegName, InvMask*) - Inverts a specified bits.
- **clrSetReg{w}Bits** (*RegName, ClrMask, SetMask*) - Clears bits specified by ClrMask and sets bits specified by SetMask

Access To Named Bits

- **testReg{w}Bit** (*RegName, BitName*) - Tests whether the bit is set.
- **setReg{w}Bit** (*RegName, BitName*) - Sets the bit to 1.
- **clrReg{w}Bit** (*RegName, BitName*) - Sets the bit to 0.
- **invertReg{w}Bit** (*RegName, BitName*) - Inverts the bit.

Access To Named Groups of Bits

- **testReg{w}BitGroup** (*RegName, GroupName*) - Tests a group of the bit for non-zero value
- **getReg{w}BitGroupVal**(*RegName, GroupName*) - Reads a value of the bits in group
- **setReg{w}BitGroupVal** (*RegName, GroupName, GroupVal*) - Sets the group of the bits to the specified value.

RegName - Register name
BitName - Name of the bit
GroupName - Name of the group
BitMask - Mask of the bit
BitsMask - Mask specifying one or more bits
BitsVal - Value of the bits masked by BitsMask
GroupMask - Mask of the group of bits
GetMask - Mask for reading bit(s)
ClrMask - Mask for clearing bit(s)
SetMask - Mask for setting bit(s)
InvMask - Mask for inverting bit(s)
RegValue - Value of the whole register
BitValue - Value of the bit (0 for 0, anything else = 1)
{w} - Width of the register (8, 16, 32). The available width of the registers depends on used platform.

Example

Assume that we have a CPU which has a PWMA channel and it is required to set three bits (0,1,5) in the PWMA_PMCTL to 1. We use the following line:

```
setRegBits(PWMA_PMCTL,35);           /* Run counter */
```

3.9. Processor Expert Files and Directories

PE Project File

All components in the project with their state and settings and all configurations are stored in one file **ProcessorExpert.pe** in the root of project directory. If the whole content of the project including subdirectories is copied or moved to another directory it is still possible to open and use it in the new location.

Project Directory Structure

Processor Expert uses the following sub-directory structure within the project directory:

- **\Generated_Code** - the directory containing all generated source code modules for components.
- **\Documentation** - the directory with the project documentation files generated by Processor Expert.
- **\Sources** - the directory for main module, event module other user modules.

Please see details on files generated by Processor Expert in *3.5.1 Code Generation*.

User templates and components

User-created templates (see chapter *3.3.5 Creating User Component Templates*) and components (created in Component Wizard, see chapter *5 Component Wizard Description*) are shared by all users and they are stored in the directory:
`%ALLUSERSPROFILE%\ApplicationData\Processor Expert\{version}\`
For example C:\Documents and Settings\All Users\ApplicationData\Processor Expert\CW08_PE3_02\

4. Processor Expert Tutorials

This tutorial is provided for embedded system designers who wish to learn quickly how to use the exclusive features of Processor Expert. Reading this tutorial may be all you need to start using Processor Expert for your own application.

The following tutorials are available:

Kinetis Project 1

4.1. Tutorial Project 1 for Kinetis Microcontrollers

This simple tutorial describes a periodically blinking LED project. The LED is connected to one pin of the CPU and it is controlled by a periodical timer interrupt.

*Please note that the project is designed to work with **MK60X256VMD100** CPU and **TWR–K60N512** tower board. However, it's not necessary to have this hardware. The project can be created without it.*

Components

This simple Processor Expert demo-project uses the following LDD Embedded Components (See *3.2.1.1 Component Categories* for details.):

1. MK60X256VMD100 - CPU component
2. GPIO_LDD - This component will control LED output, connected to PTA10 pin.
3. TimerUnit_LDD - This component will provide periodical timing.

Steps

This tutorial contains the following main steps:

1. Creating a new project
2. Adding and renaming components
3. Configuring components
4. Generating and writing code

4.1.1. Tutorial Project 1 for Kinetis, Step 1

Creating a New Project

1. In the CodeWarrior, click on the command **New / Bareboard Project...** in the menu *File* in the CodeWarrior window in order to create a new project.
2. The Project Wizard dialog window appears. Enter the name of the project - "LED". Click on the *Next* button.
3. Select **Kinetis / MK60 / MK60X256VMD100**. Click on the *Next* button.
4. *P&E USB BDM Multilink* is set as the default connection. Click on the *Next* button.
5. Skip addition of existing files by clicking on the *Next* button.
6. C is set in 'Languages' dialog. Continue by clicking on the *Next* button.
7. Select the *Processor Expert* from *Rapid Application Development* and click on the *Next* button.
8. Confirm the dialog *Select configurations* by clicking on the "OK" button.
9. Select the **MK60X256VMD100** in "MCU Pin variants" and th 'INTERNAL_RAM for

MK60X256VMD100' in "Configurations". Click on the *Finish* button.

Now the new empty project is created and ready for adding new components.

Next step

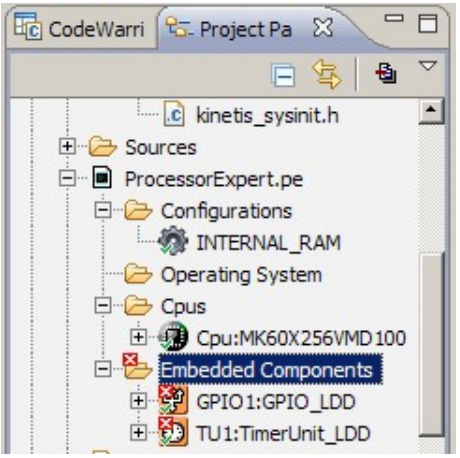
Go to Step 2 - Adding components to the project.

4.1.2. Tutorial Project 1 for Kinetis, Step 2

Adding components

1. In the Components Library window switch to **Alphabetical** tab and find a **GPIO_LDD** component and in its pop-up menu (invoked by the right mouse button) select '**Add to project**'.
2. Find **TimerUnit_LDD** component and in its pop-up menu (invoked by the right mouse button) select '**Add to Project**'.

The components are now visible in the Component folder in the Project Panel.



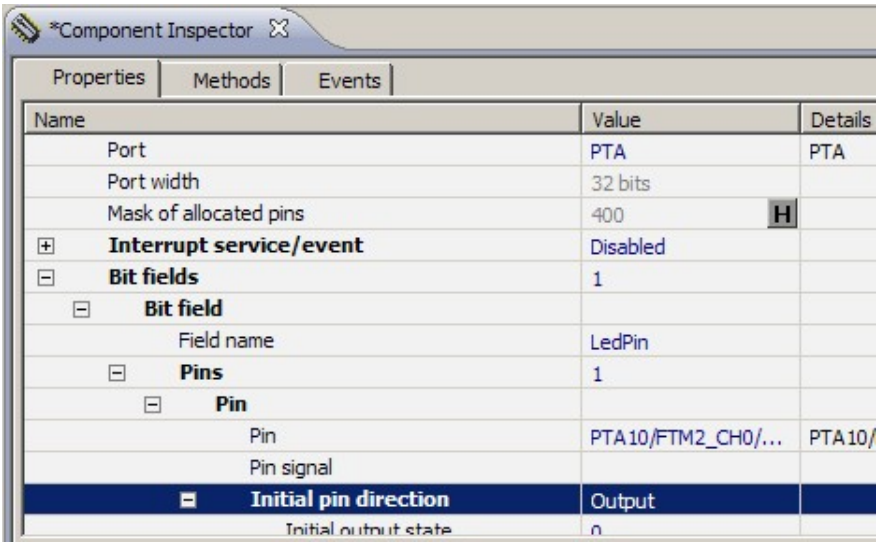
Next step

Go to Step 3 - Configuring components

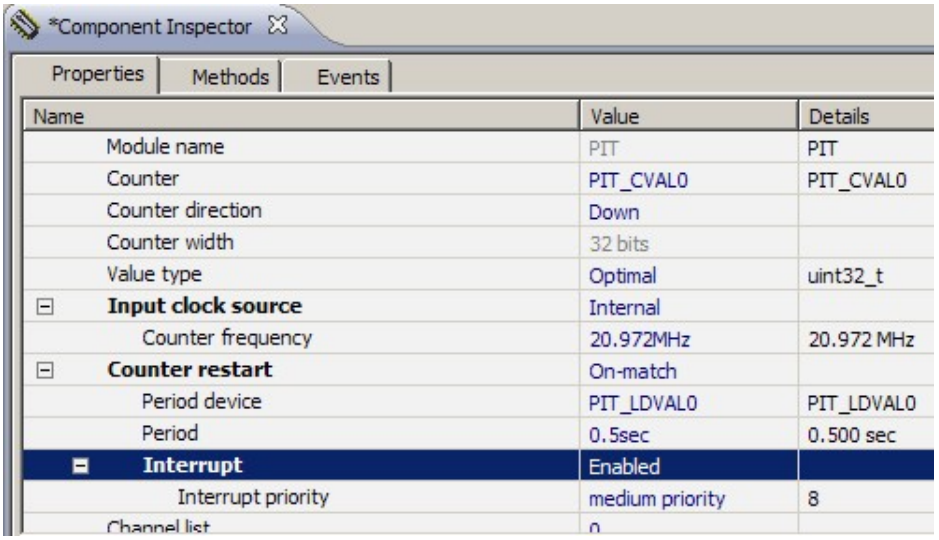
4.1.3. Tutorial Project 1 for Kinetis, Step 3

Configuring components

1. Click on the **GPIO1** GPIO_LDD component to open it in **Component Inspector** view.
2. In the Component Inspector set the property **Field name** in the first Bit field group to **LedPin**. Select pin PTA10 (it corresponds to LED17 on the tower board). Then set the **Initial pin direction** property to **Output**.



3. In the Project Panel click on the **TU1** TimerUnit_LDD component to open it in the **Component Inspector** .
4. Set the following properties:
   - **Counter** to **PIT_CVAL0**
   - **Counter direction** to **Down**
   - **Counter restart** to **On-match**. This will allow to set desired period of interrupt, otherwise interrupt invocation period is fixed to counter overflow.
   - **Counter frequency** - use the dialog button and select the only value offered in the right pane: 20.972MHz.
   - **Counter restart / Period** - click on the dialog button and set Init. value to **0.5 sec**
   - **Interrupt** to **Enabled**



Next step

Go to Step 4 - Code

4.1.4. Tutorial Project 1 for Kinetis, Step 4

Code Generation

1. Generate code using the menu command **Project / Generate Processor Expert Code**. This process generates source files for components to the "Generated Code" folder in the CodeWarrior project window. The other modules can be found in the "Sources" folder.

Writing Application Code

2. Go back to the Project Panel and open the **Sources / ProcessorExpert.c** module. This is Processor Expert main module. Do the following modifications:

   Declare global variables of type LDD_TDeviceData by adding this line before main function:

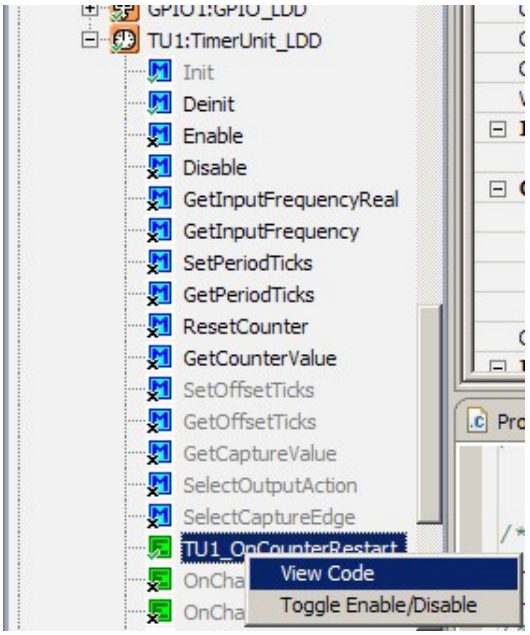
   ```
   LDD_TDeviceData *LedData;
   LDD_TDeviceData *TimerData;
   ```

   In main function after PE_low_level_init(); call components initialization functions:

   ```
   TimerData = TU1_Init(NULL);
   LedData = GPIO1_Init(NULL);
   ```

```
#include "IO_Map.h"

/* User includes (#include below this line is not maintained b

LDD_TDeviceData *LedData;
LDD_TDeviceData *TimerData;

void main(void)
{
  /* Write your local variable definition here */

  /*** Processor Expert internal initialization. DON'T REMOVE
  PE_low_level_init();
  /*** End of Processor Expert internal initialization.

  /* Write your code here */
  TimerData = TU1_Init(NULL);
  LedData = GPIO1_Init(NULL);
  /* For example: for(;;) { } */
```

3. In the project panel unfold the **TU1** component's list of events and methods. Open the code of the **TU1_OnCounterRestart** in editor using the pop-up menu command 'View Code'.



4. Insert the following lines into the **TU1_OnCounterRestart** event handler function body:

```
extern LDD_TDeviceData *LedData;
GPIO1_ToggleFieldBits(LedData,LedPin,1);
```

```
void TU1_OnCounterRestart(LDD_TUserData *UserDataPtr)
{
    extern LDD_TDeviceData *LedData;
    GPIO1_ToggleFieldBits(LedData,LedPin,1);
}
```

Running the Application

5. Build the project using the **Project / Build** command from the CodeWarrior menu.
6. If you have the TWR–K60N512 board, connect it now. Run and debug the application using the **Run / Run** command from the CodeWarrior menu. After the application is run, the on-board LED should start blinking.

5. Component Wizard Description

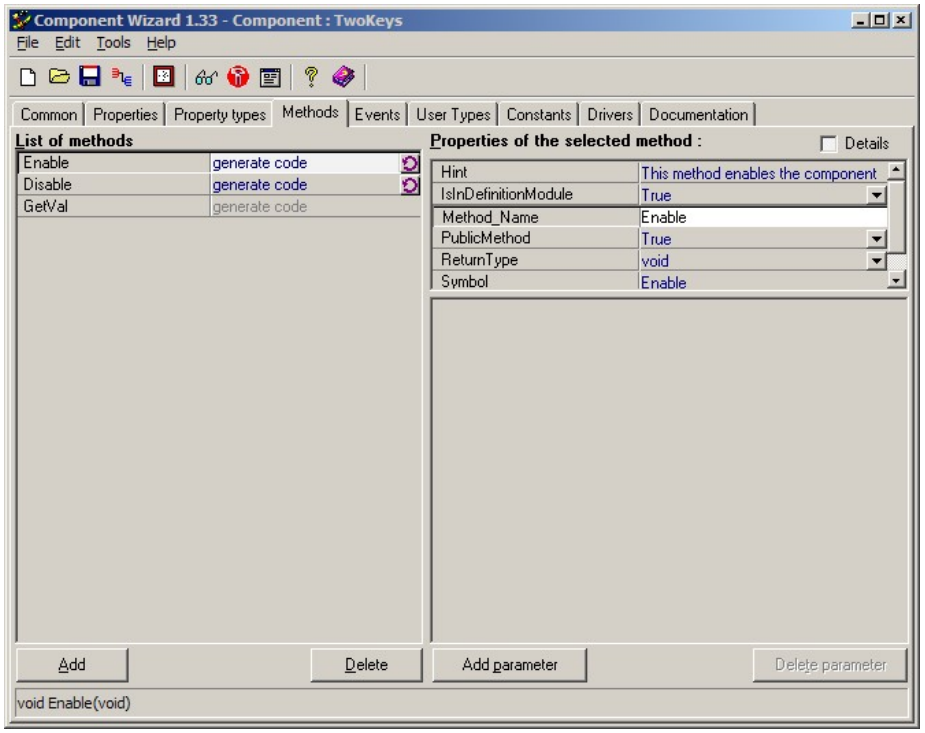
Component Wizard is a tool dedicated to the creation and edition of Embedded Components. See *3.2.1 Embedded Components* for details. It provides a powerful interface for the composition of new components, and generates the component files.

Using Component Wizard, the user can create new components very quickly and easily without errors in the generated files. The user needs only to determine the Properties, Methods and Events and write the necessary implementations of the methods and events.

Component Wizard facilitates the reusability of existing Components and helps edit the source code (quick location, editor, ...).

Component Wizard is an **external tool**, not a part of Processor Expert.

For further information, see Component Wizard Help.



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